Sheet Metal Industries

The only Journal in the World wholly devoted to the Manufacture, Manipulation, Fabrication, Welding, Assembly and Finishing of Ferrous and Non-Ferrous Sheet and Strip

VOL. 38 : No. 415 NOVEMBER 1961 PRICE 2/6

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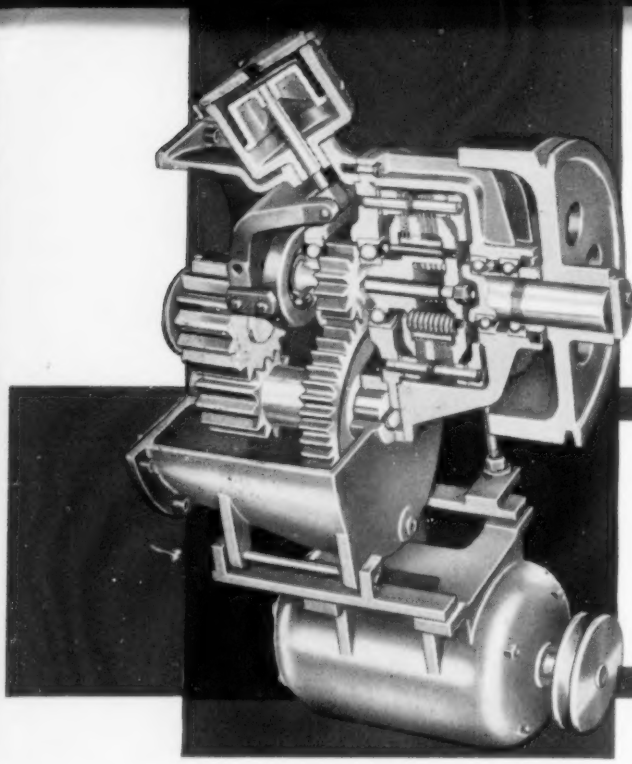

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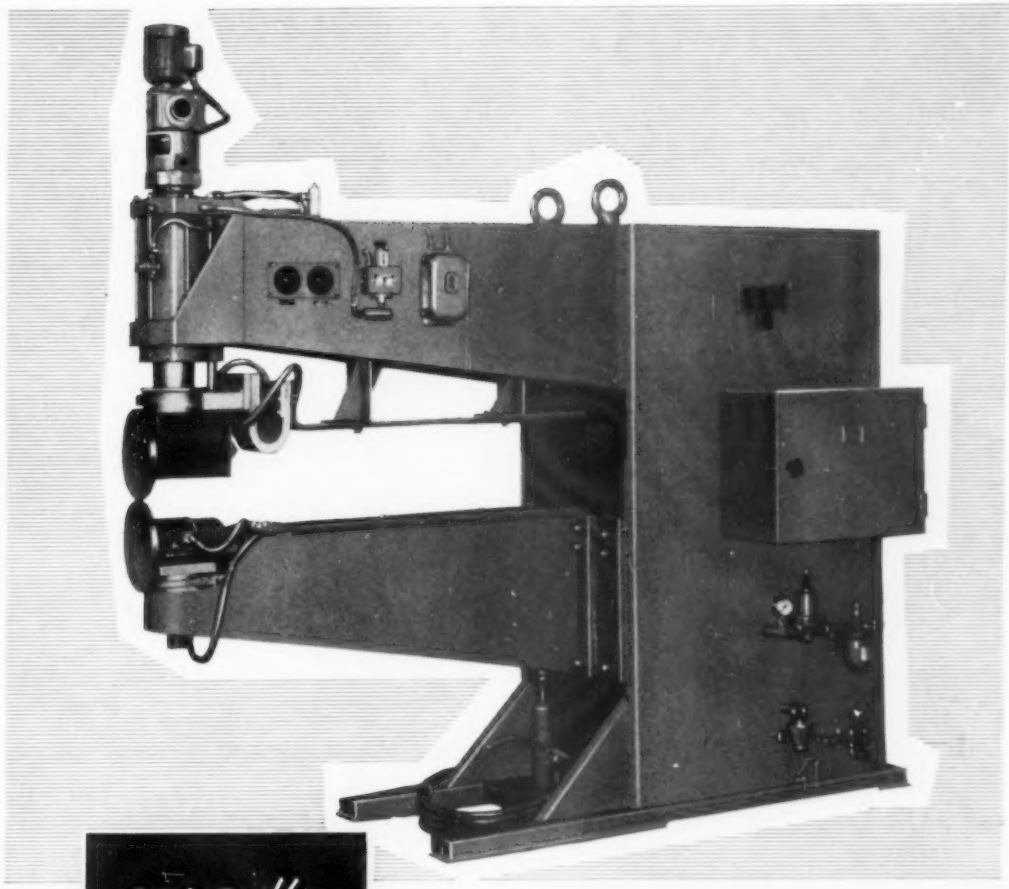

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Editorial Contents: 781, 783

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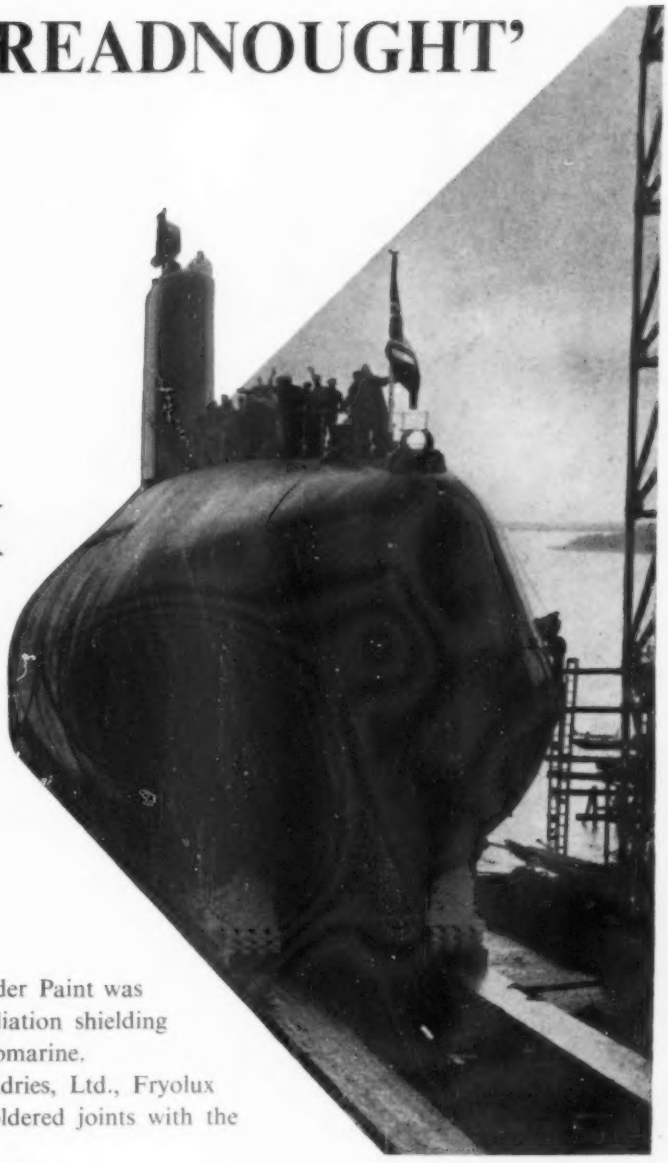

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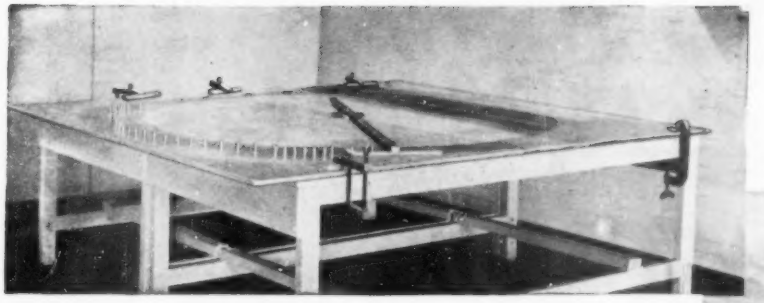

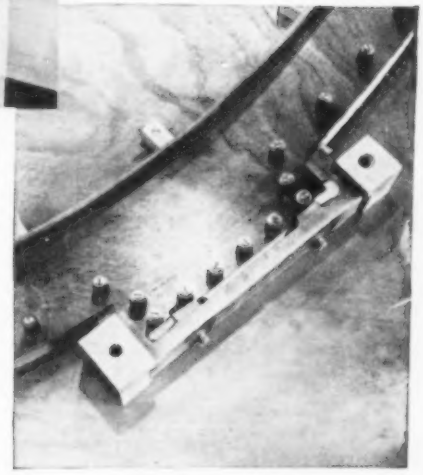

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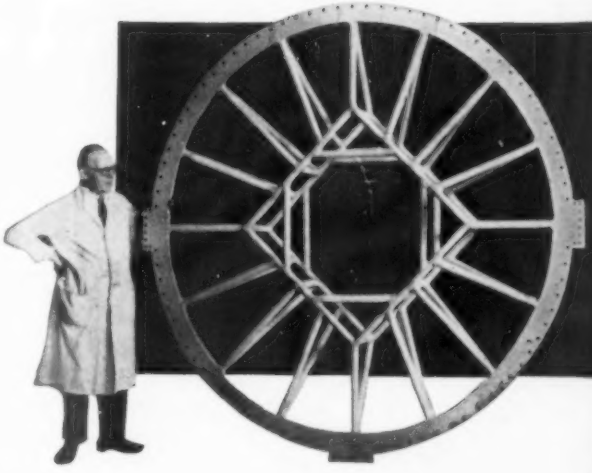

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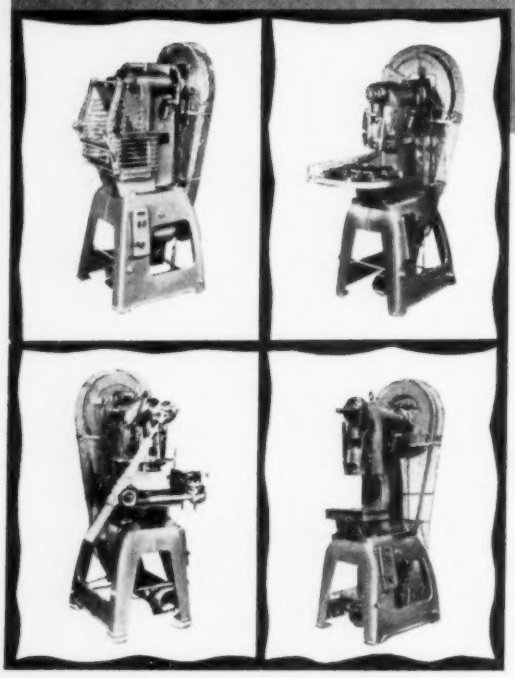

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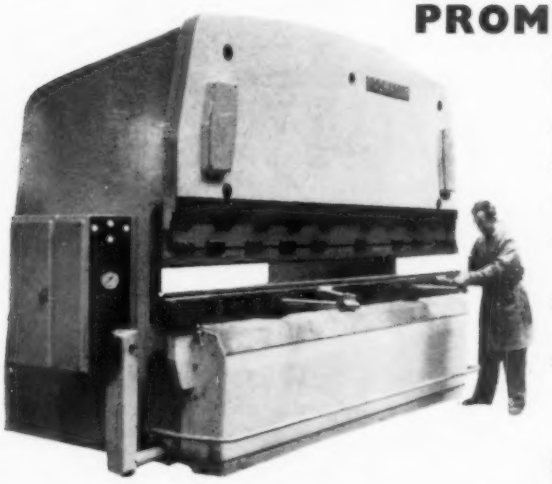

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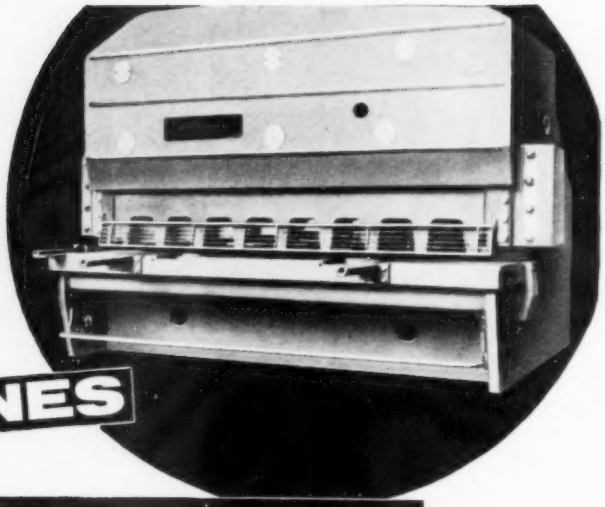

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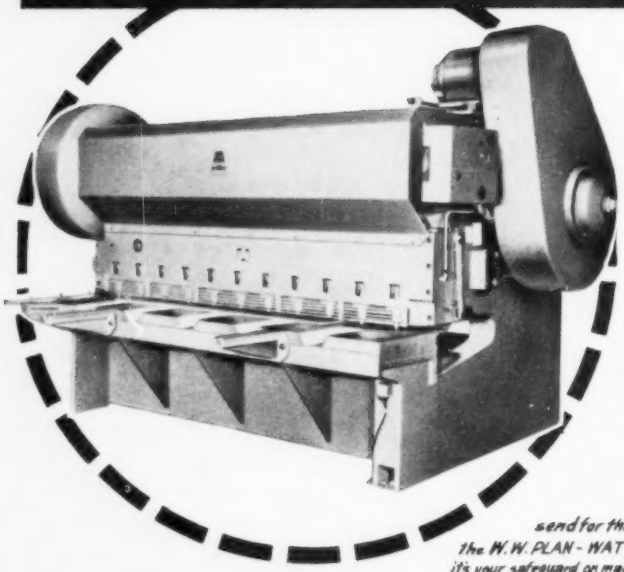
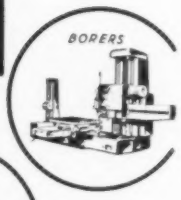
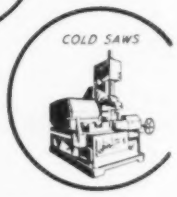
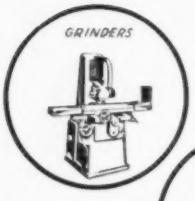
ScTP 16 x 3150	$\frac{3}{8}$" x 10'4"	2'$\frac{3}{4}$"	17 tons	32	









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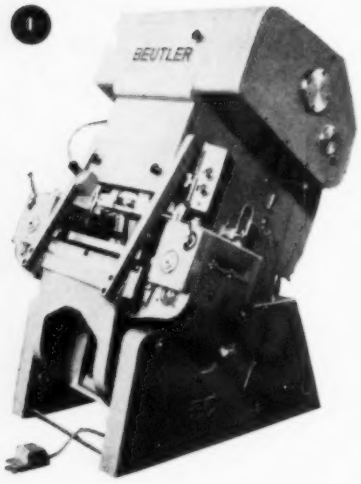

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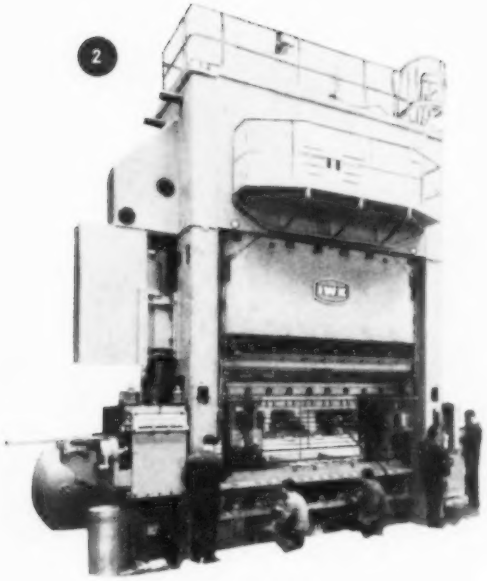

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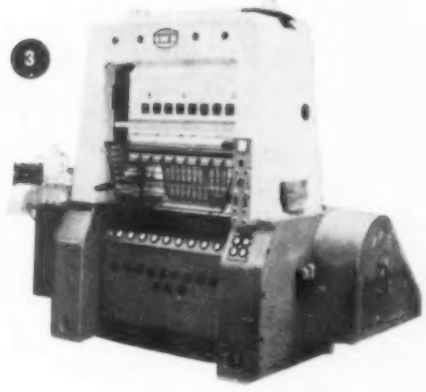

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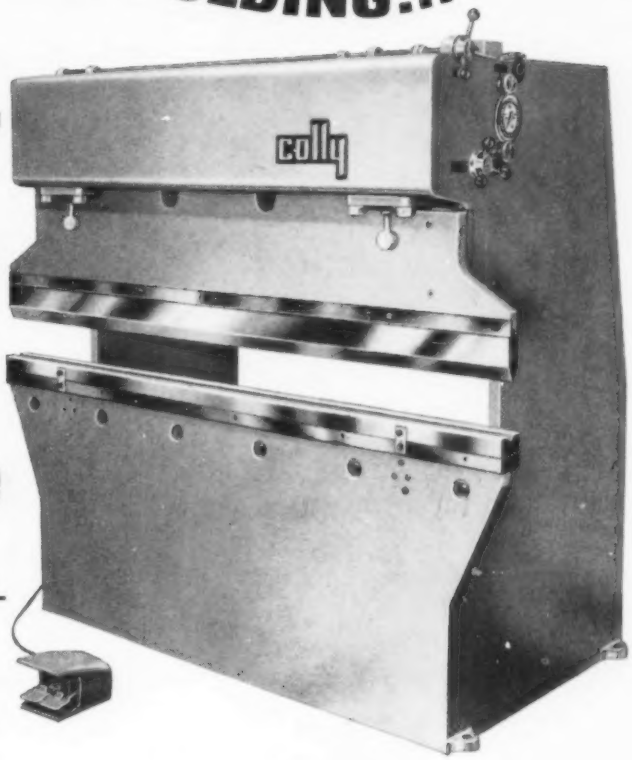

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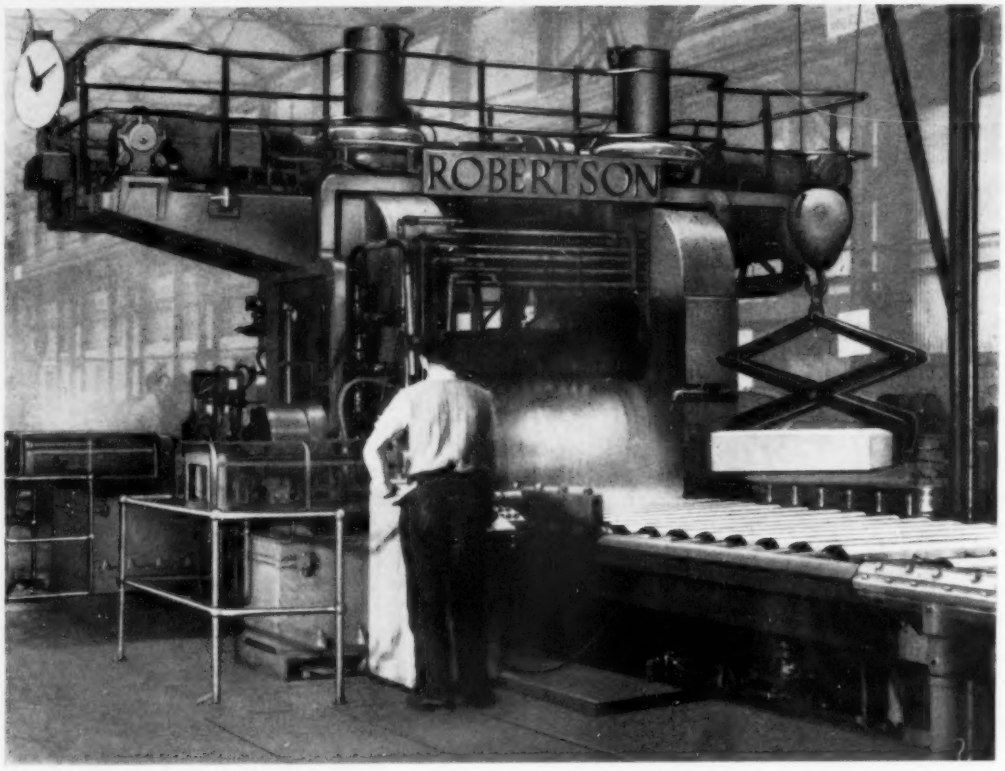

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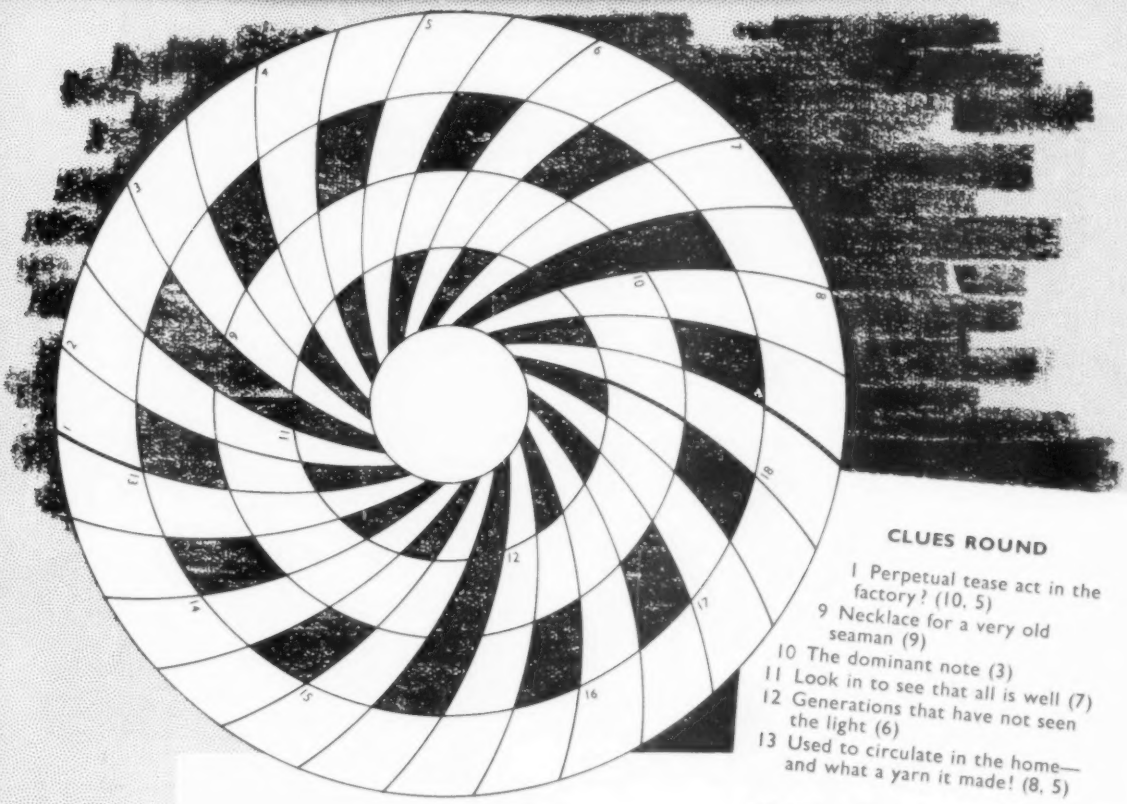

CLUES ROUND

1 Perpetual tease act in the factory? (10, 5)
9 Necklace for a very old seaman (9)
10 The dominant note (3)
11 Look in to see that all is well (7)
12 Generations that have not seen the light (6)
13 Used to circulate in the home—and what a yarn it made! (8, 5)

CLUES RADIAL

(Clues 13 to 18 to be read from the centre)

2 She would encourage the patient to turn the corner (5)
3 The horse can take a good pull at it (5)
4 Old coin not for the commoner (5)
5 Ready for a sea change—of direction (2, 3, 4)
6 Heart of 2 (5)
7 A test of cultural faculty (5)
8 Does the outcome question Susan's existence? (5)
13 Sees a reformation (5)
14 Some of the clientele mistrust the sticky stuff (5)
15 What every consumer has done (5)
16 Natural aid to the thruster (5)
17 Always, that is, weird (5)
18 A secret helicopter flight put her in hiding (5)

Centripetal...

. . . the opposite to "flying off the handle" (generally associated with tearing off the wrong kind of strip).

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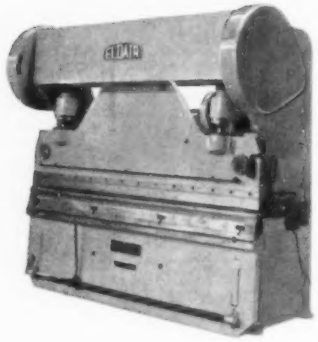
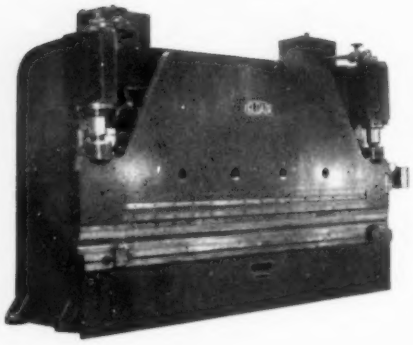


Hydraulic and Mechanical



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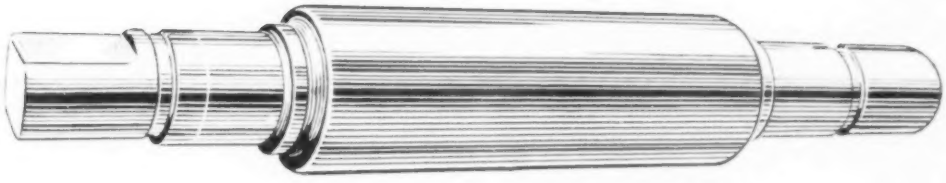

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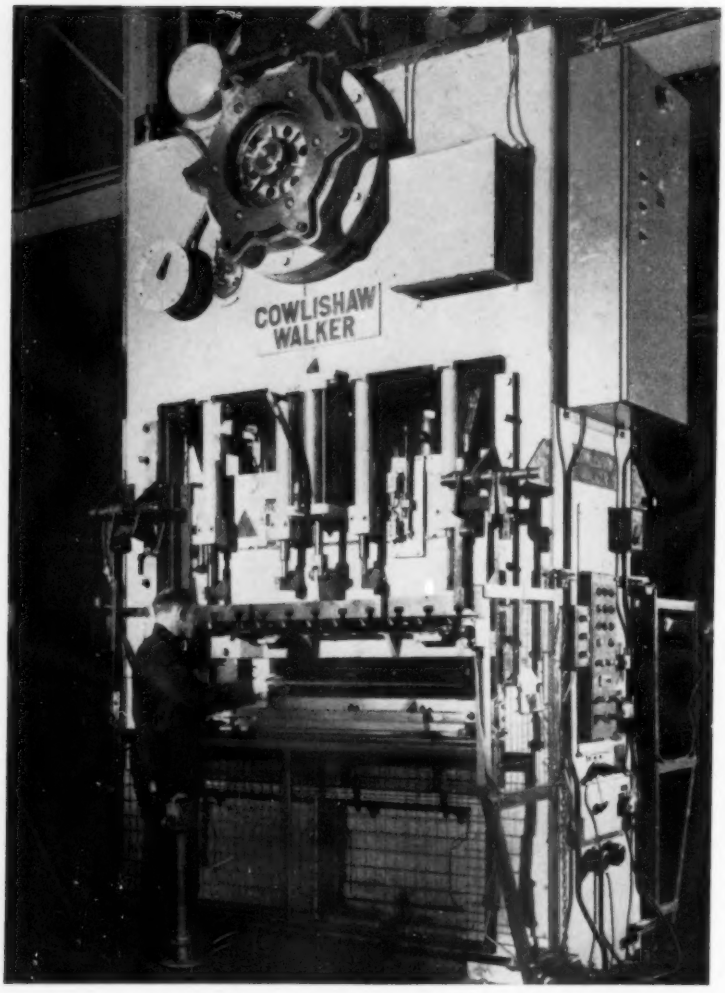

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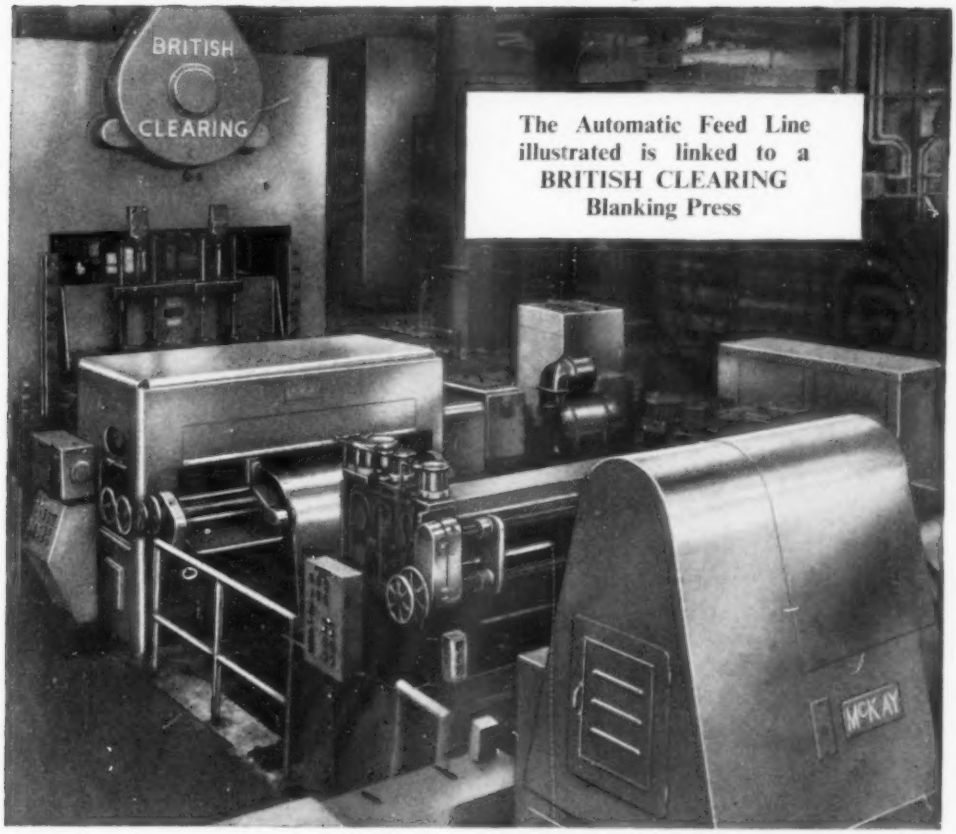

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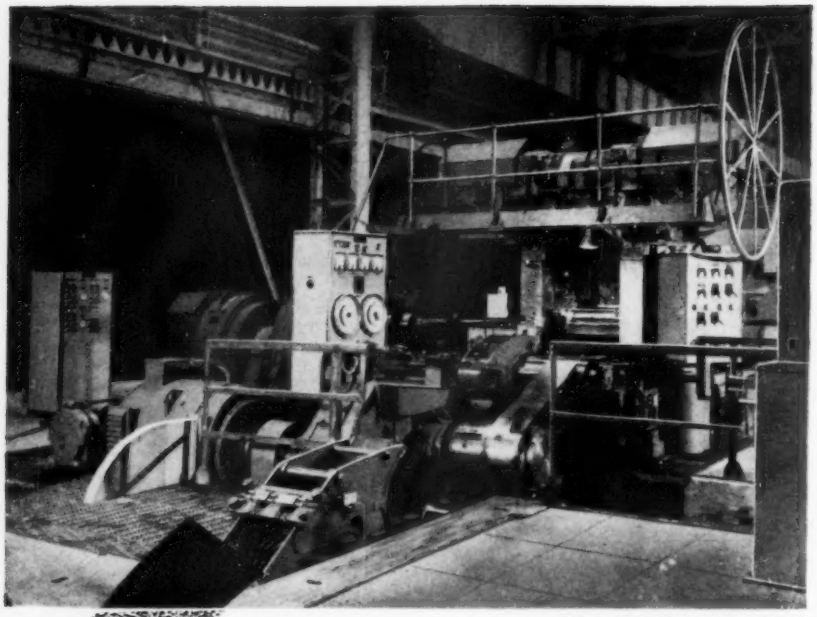

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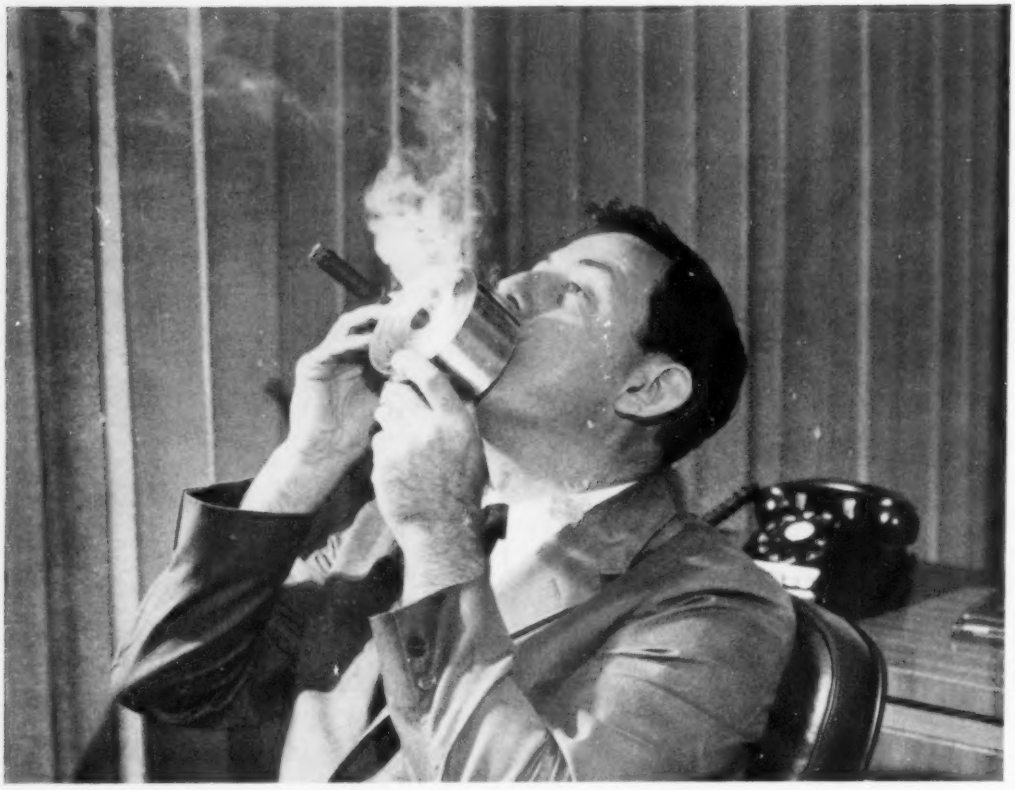

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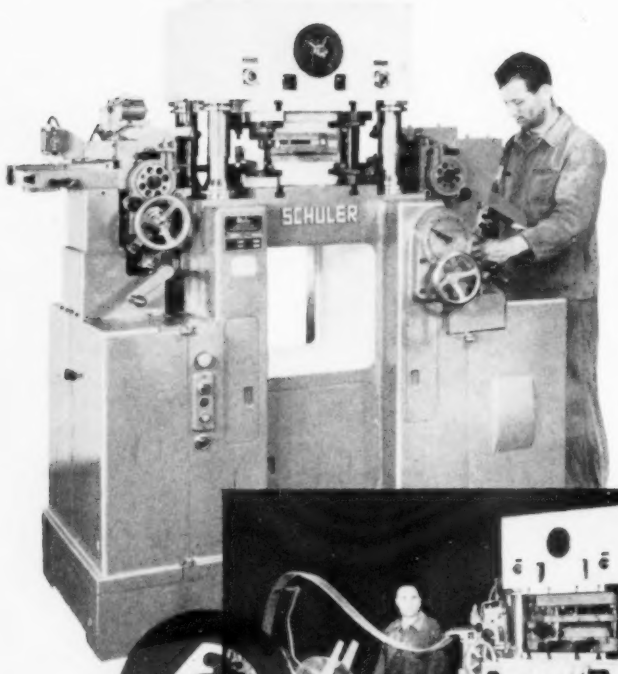

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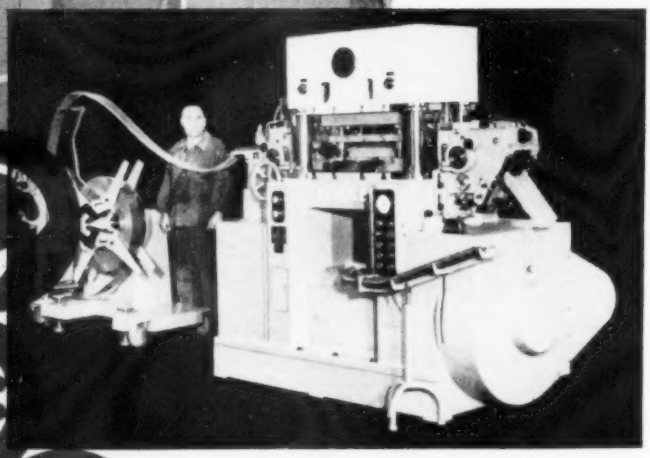

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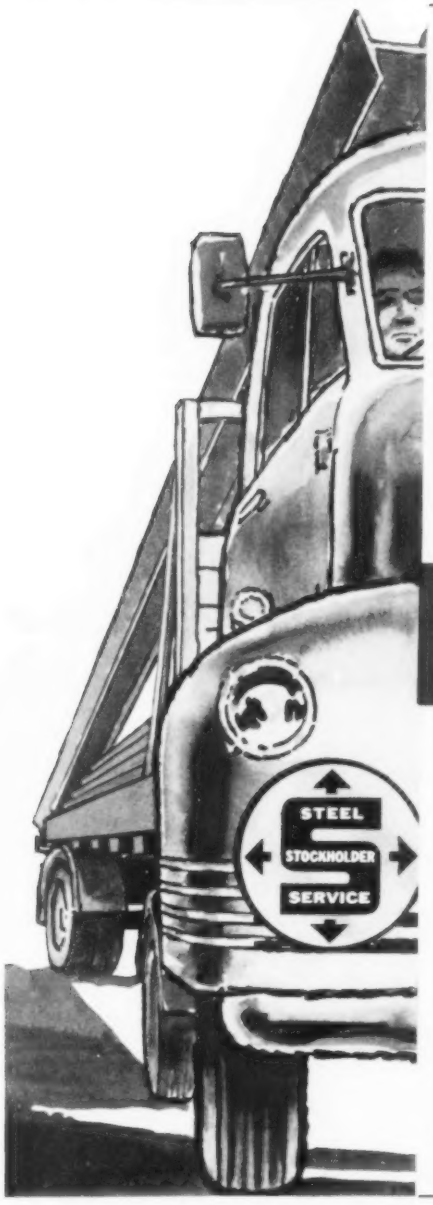

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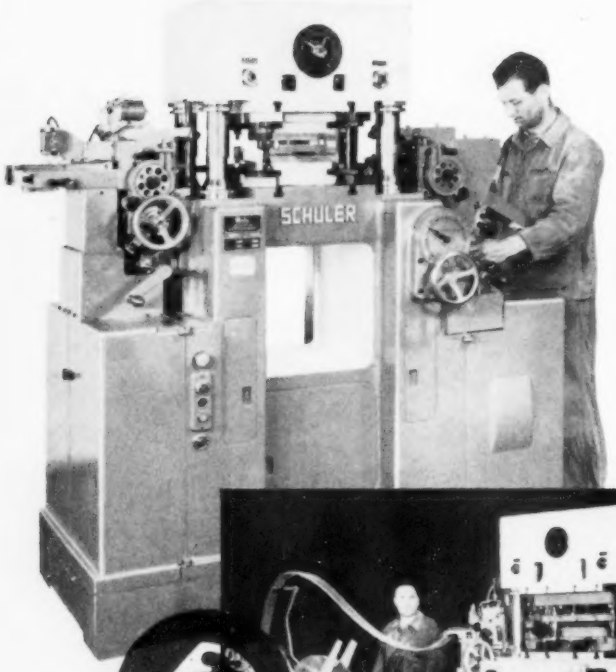

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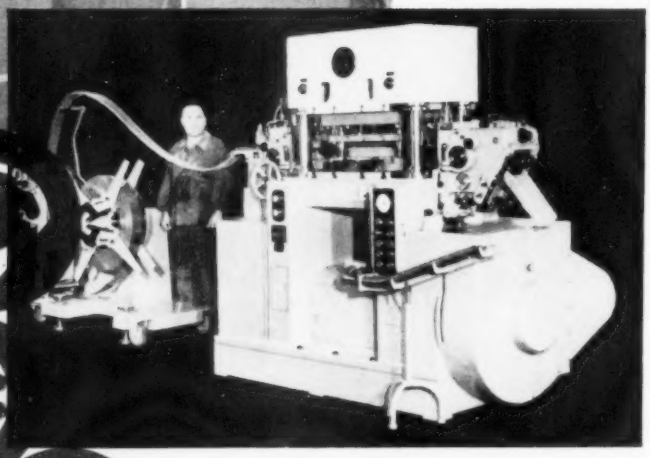

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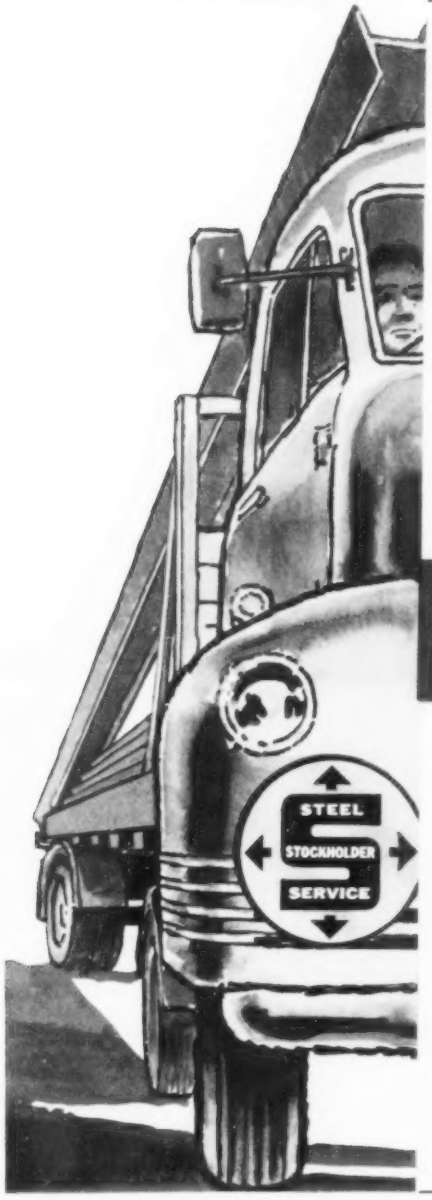

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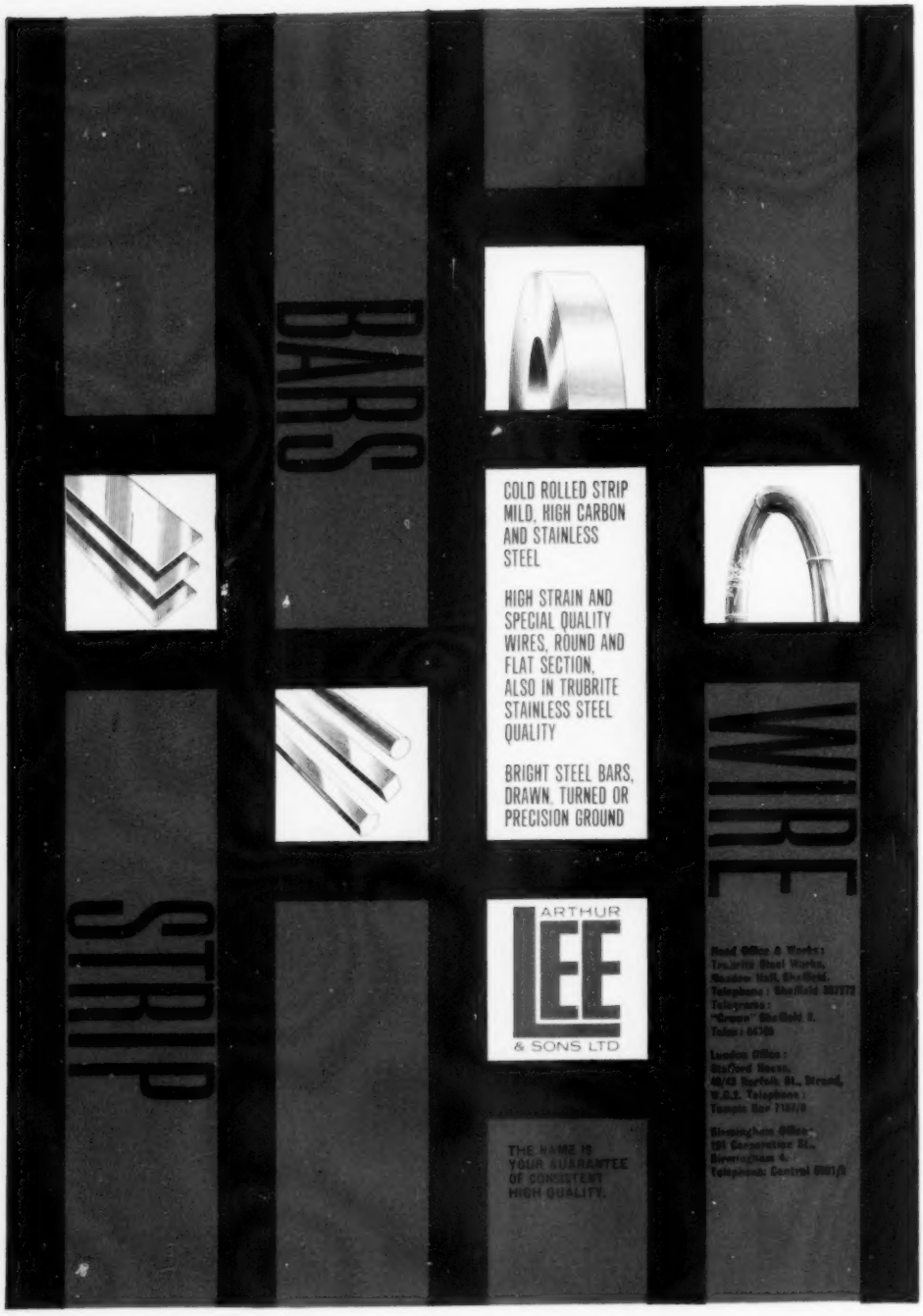
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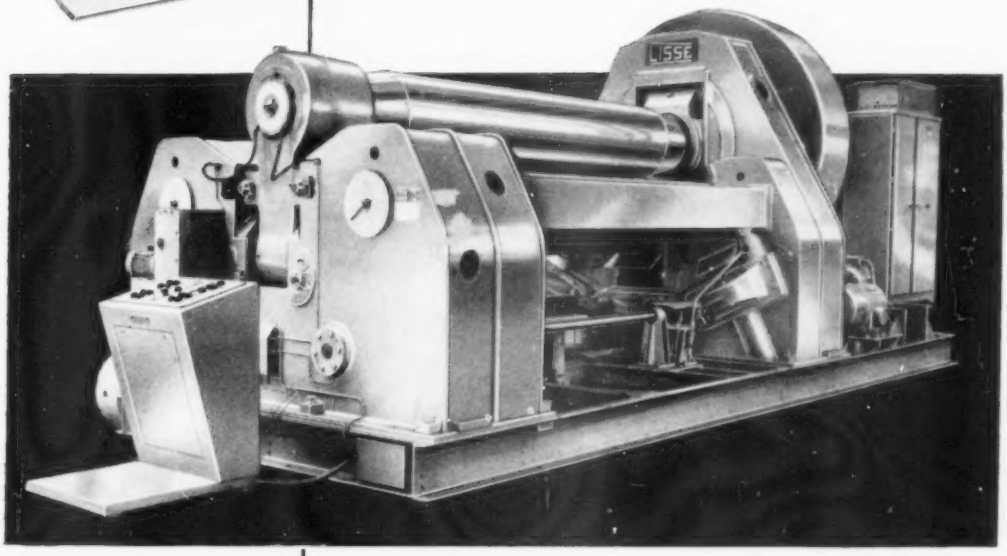

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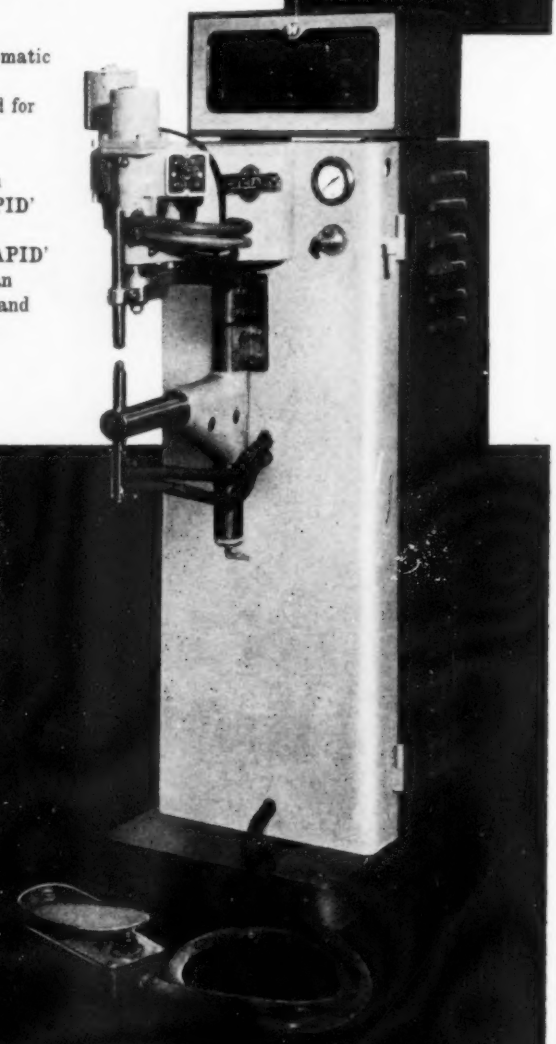

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	18"	.072"+.072"	.250"+.250" dia.
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	24"	.125"+.125"	.375"+.375" dia.
	30"	.104"+.104"	.375"+.375" dia.
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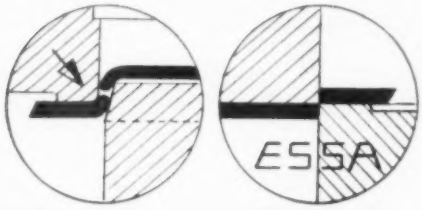

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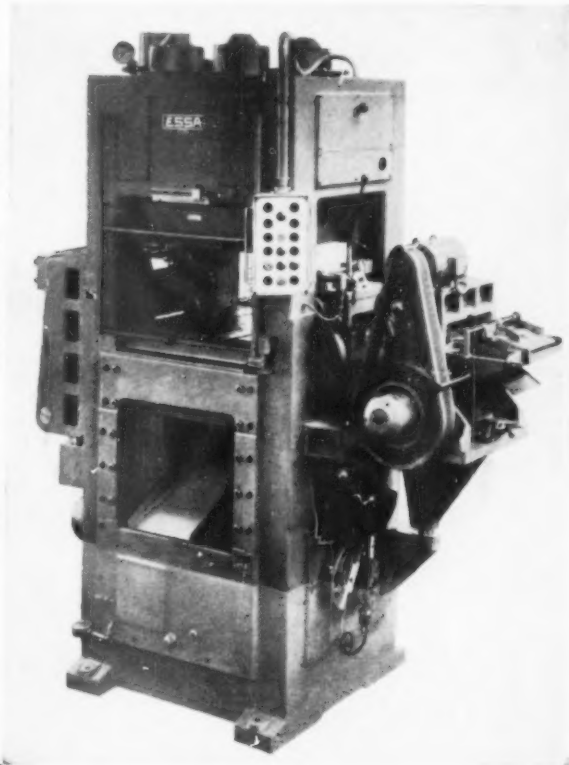

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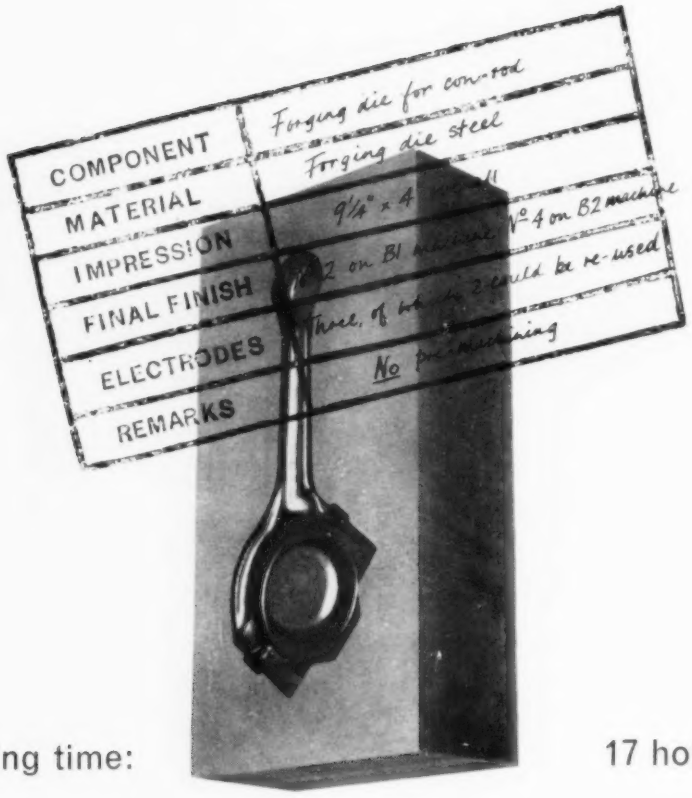

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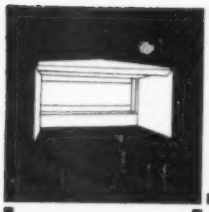
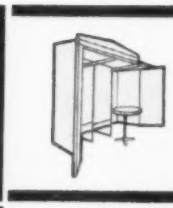
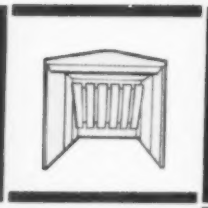
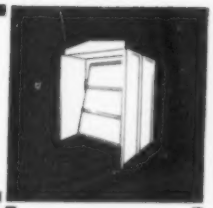
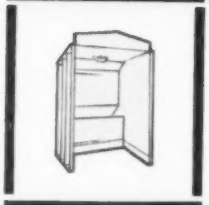
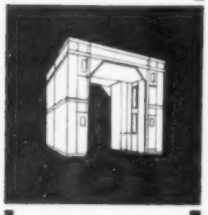
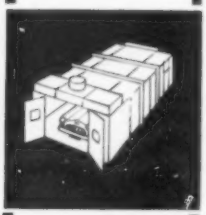
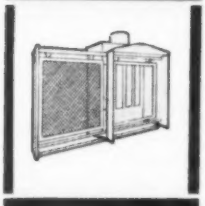
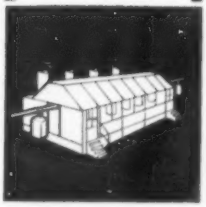



SPRAY BOOTHS





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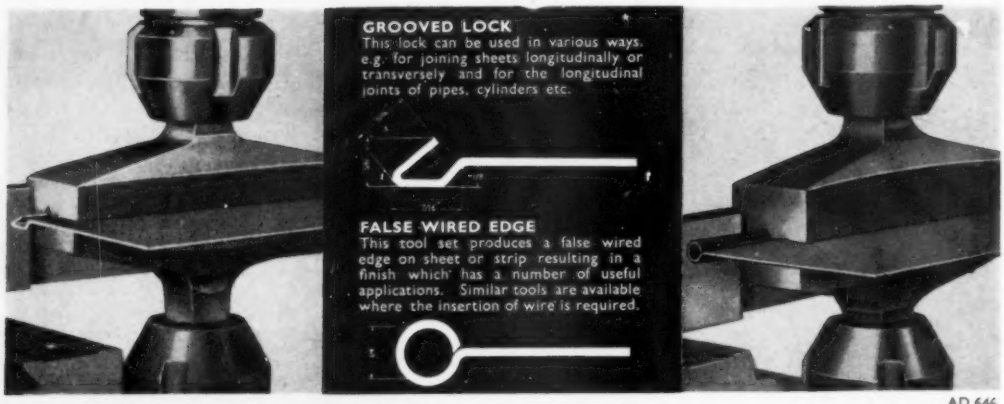
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Increased Tool Life and Production

Better workpiece finish with BLACK-MOLY

With the demand for higher production and the use of modern materials, it is imperative to have the maximum efficiency from any machining operation. Specially chosen base oils containing guaranteed pure micronated Molybdenum Disulphide, which make up the range of Black-Moly Cutting Fluids, have gone a long way to providing such efficiency.

Tests carried out under actual production conditions and with the co-operation of some of the largest engineering groups in this country, prove emphatically that BLACK-MOLY CUTTING FLUIDS ARE SUPERIOR. Results include tool life increases up to 40% and production increases of 300% to 500%.

BLACK-MOLY CUTTING FLUIDS INCLUDE SOLUBLE TYPES AND STRAIGHT TYPES

Our technical engineers are entirely at your disposal for help and assistance in advising the correct grade for any tricky machining problem.

Extracts from a recent P.E.R.A. report on comparison between BLACK-MOLY SOLUBLE CUTTING OIL and the same SOLUBLE CUTTING OIL WITHOUT BLACK-MOLY. Tests included drilling and turning on alloy steel EN.25 heat treated to 70 ton U.T.S. condition.

"It was established that as the cutting speed and feed rate were increased, the differences between the cutting fluids became noticeable. At cutting speeds 70 and 80 ft. per min. and feed rate 0.0138 in. per rev. the tool life was greater using the molybdenised cutting fluid, than the tool life obtained by using the straight soluble cutting fluid."

Cutting Speed ft. per min.	Feed Rate in. per rev.	* TOOL LIFE (min.)	
		Straight Soluble Cutting Fluid	Molybdenised Cutting Fluid
70	0.0138	43	60
80	0.0138	2½	15

Depth of cut 0.100 in.

* *High speed steel tool life expressed as the actual cutting time measured in minutes before tool failure. The tool was considered to have failed when the maximum wear exceeded 0.040 in. on the nose radius of the tool.*

"The results of the tests show that molybdenised cutting fluid improves the life of the turning tool when severe cutting conditions are used"

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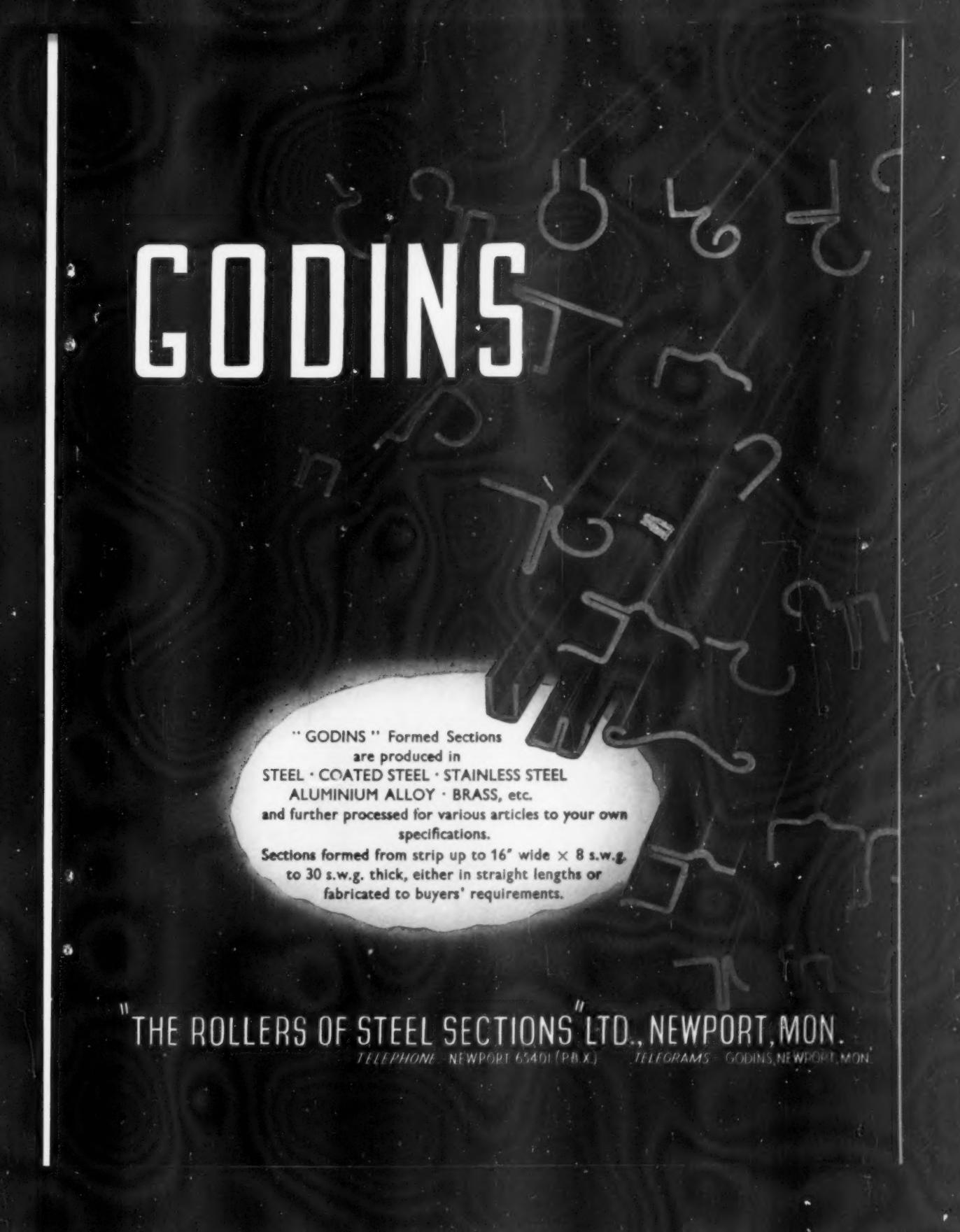
GODINS



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RHODES

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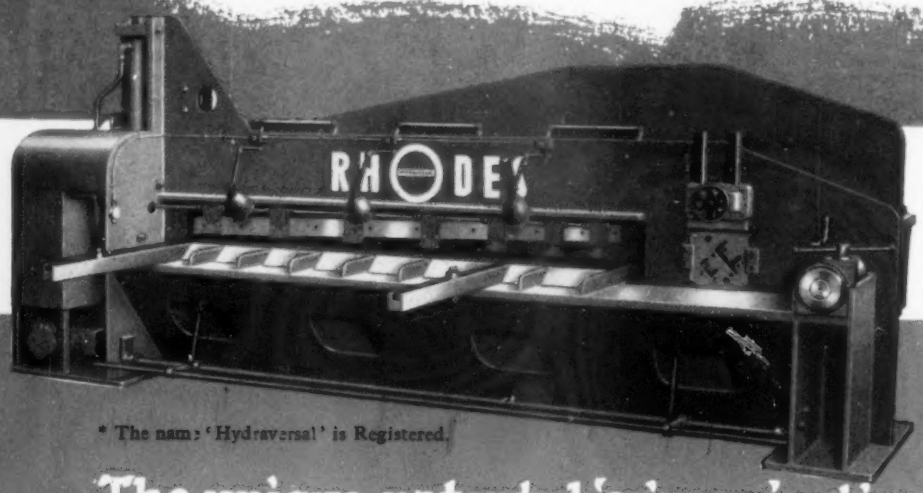
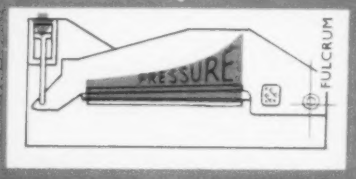
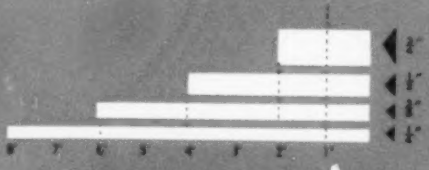


* The name 'Hydraversal' is Registered.

The unique patented 'scissors' action !

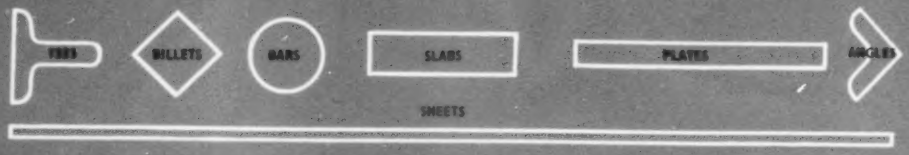


The rake of the top blade is inclined upwards *towards* the fulcrum of the 'scissors', giving progressively increasing pressure.



The shorter the cut the greater the capacity of the shears; heavy cropping operations can be done.

cuts any of these . . .



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RHS 3

THESE NEW
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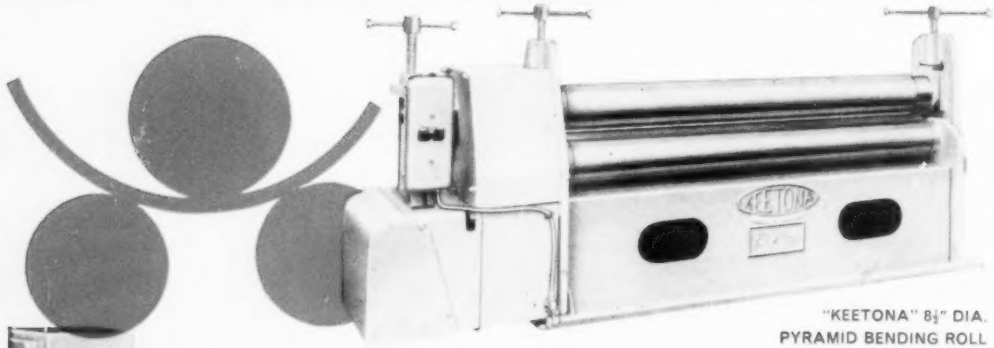
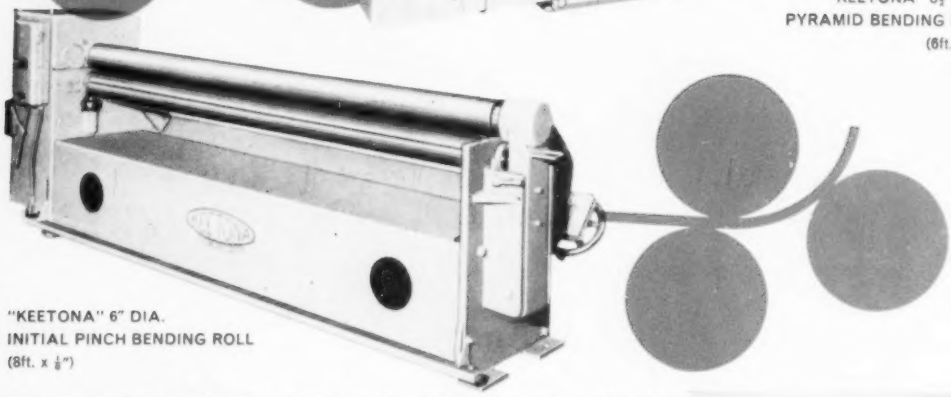


"KEETONA" 8½" DIA.
PYRAMID BENDING ROLL
(6ft. x ½")

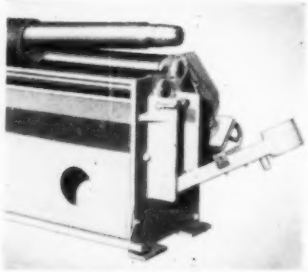


"KEETONA" 6" DIA.
INITIAL PINCH BENDING ROLL
(8ft. x ⅜")

This range of all steel Bending Rolls is designed for quick and easy forming of true cylinders. Adjustments for thickness and curvature are made easily and formed cylinders can be quickly removed, giving increased productivity. As with all new "Keetona" machine tools, these Bending Rolls are of fabricated steel construction for strength and rigidity. Other outstanding features include

- ✲ Full length safety bar—to prevent accidents
- ✲ Fully balanced drop end—to cut operator's fatigue
- ✲ Precision gearing—to ensure long service
- ✲ Grouped lubrication points for ease of maintenance

The range includes Bending Rolls of Initial Pinch and Pyramid types with rolls from 3" dia. to 8½" dia., in capacities from 16 g. sheet to ½" plate.



Counterbalanced drop end bearing in lowered position on 6" dia. Initial Pinch Roll.

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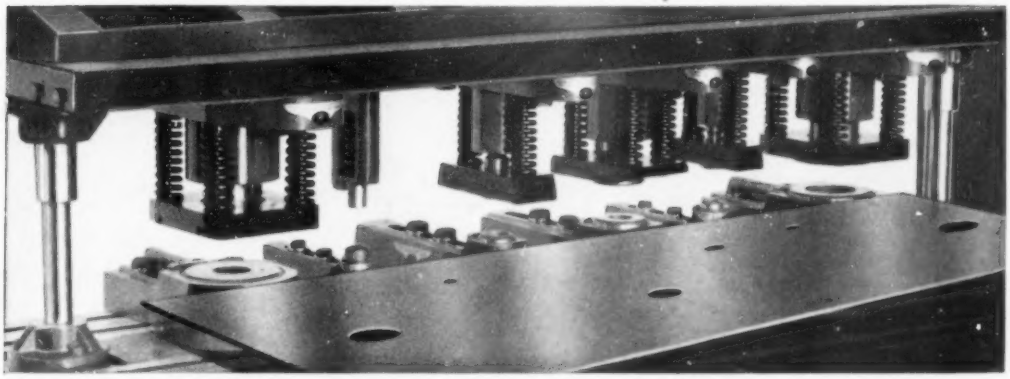
Component Setting is by Standard Redman Template in bottom bolster, by Master Template, or by linear measurement. While Punch and Die Setting is by positive Punch to Die, or by size plug to die, obviating the nipping of punches.



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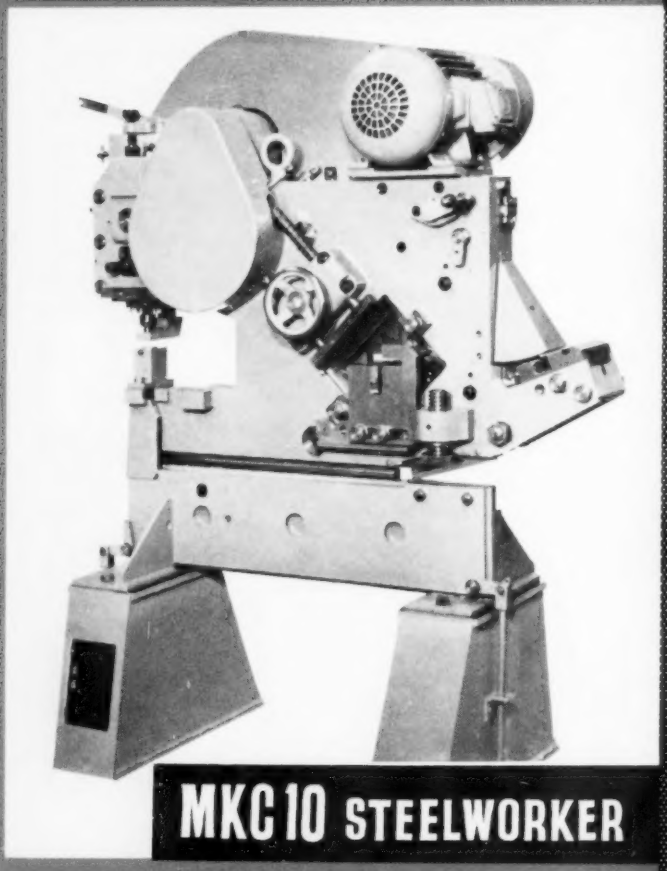

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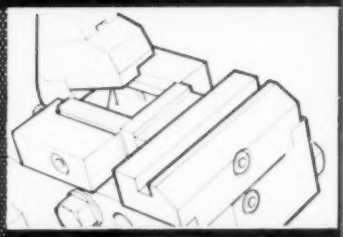
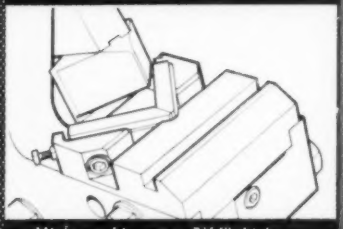
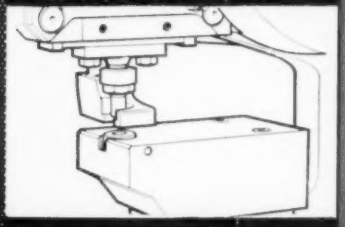


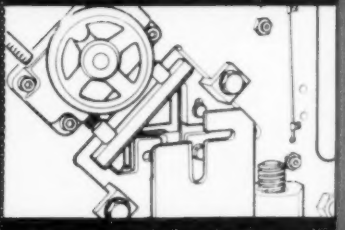
Square notching up to 3/8" thickness.



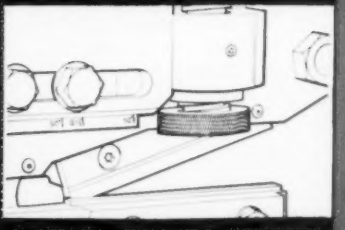
Mitre notching up to 5/16" thickness. Alternative to square notcher or supplied extra if both required.



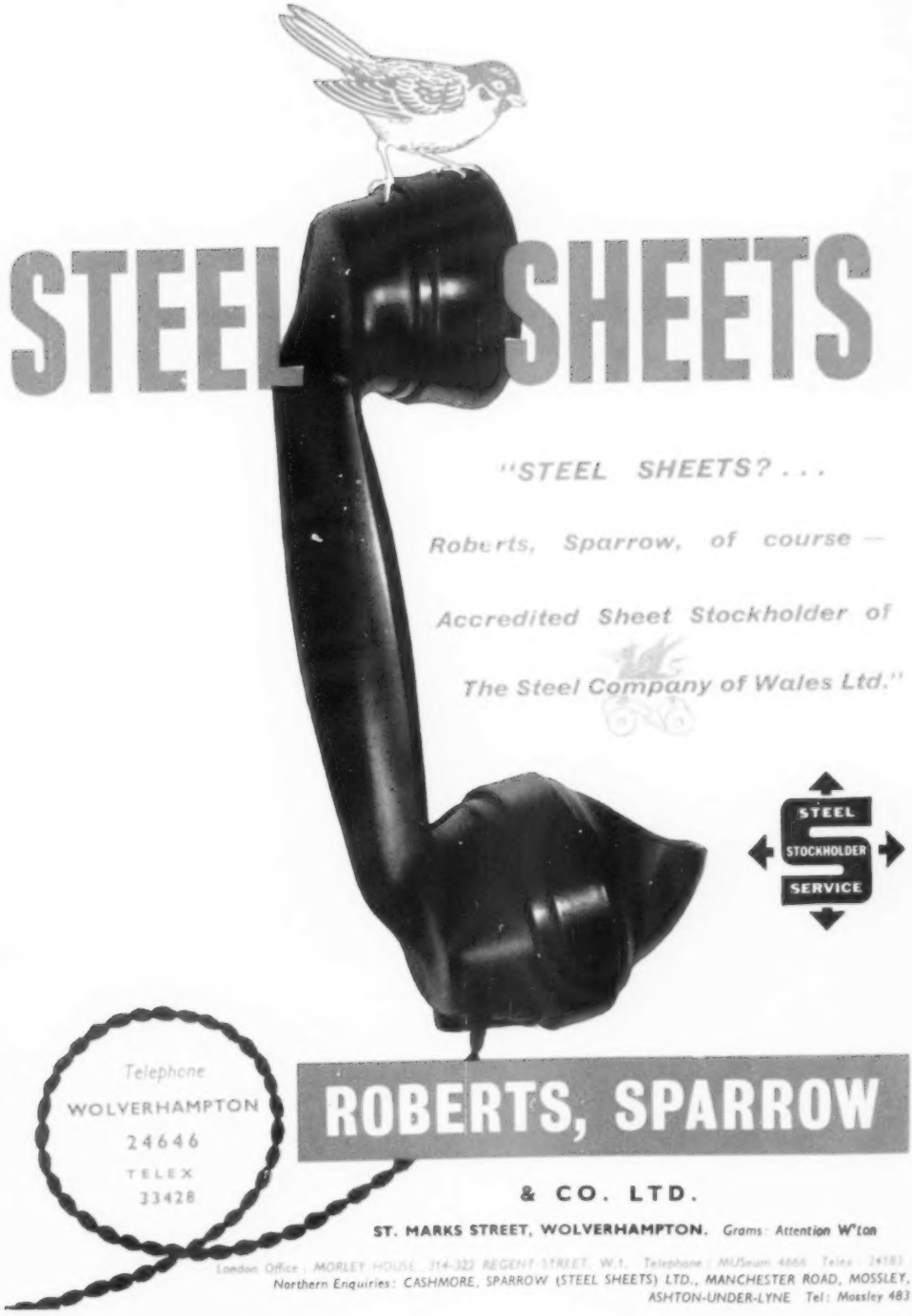
Optional die saddle for punching into flanges of joists and channels.



Cropping up to 3" × 3" × 3/8" angles and tees.



Shearing up to 3/8" thickness.



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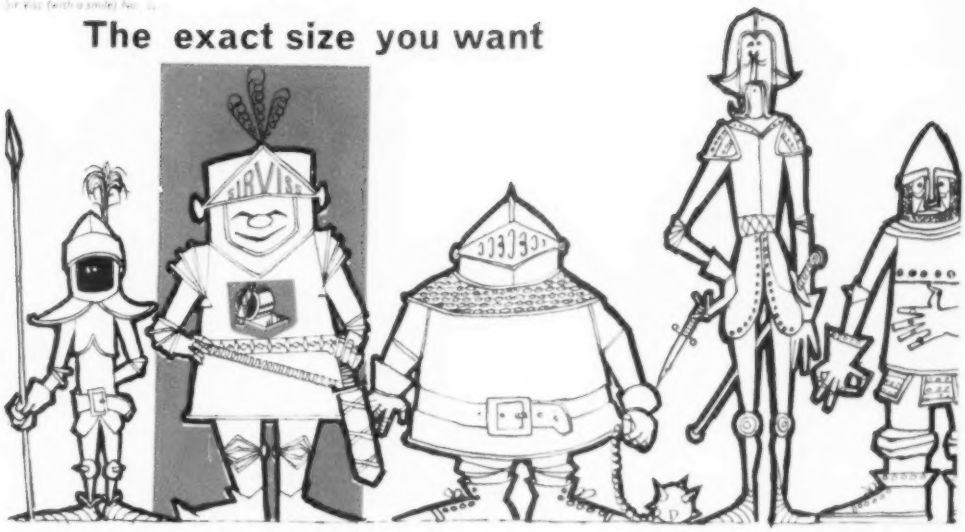

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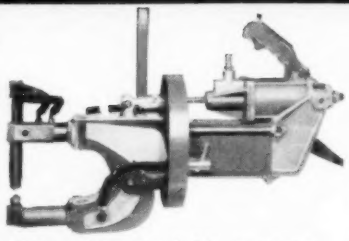

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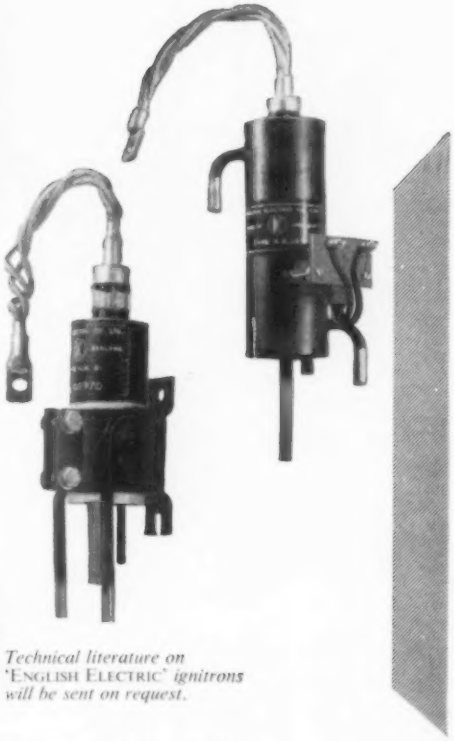

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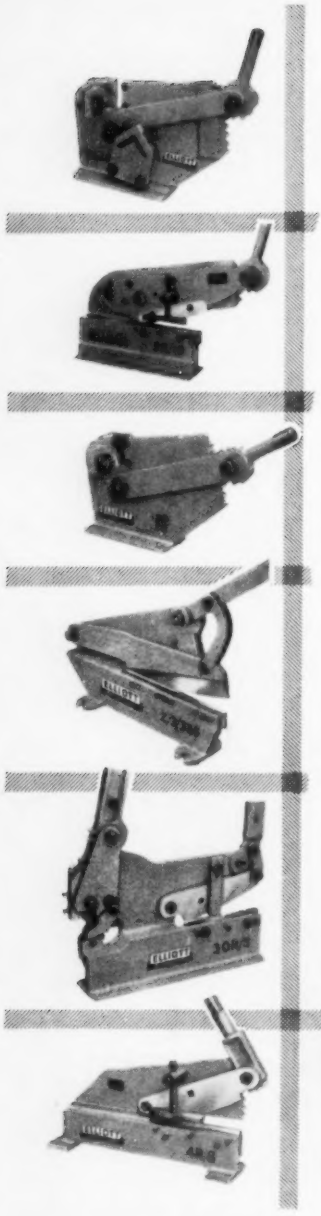

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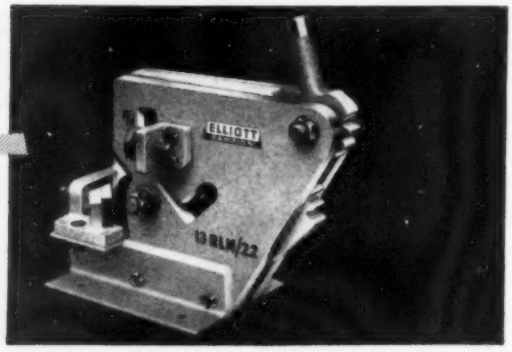

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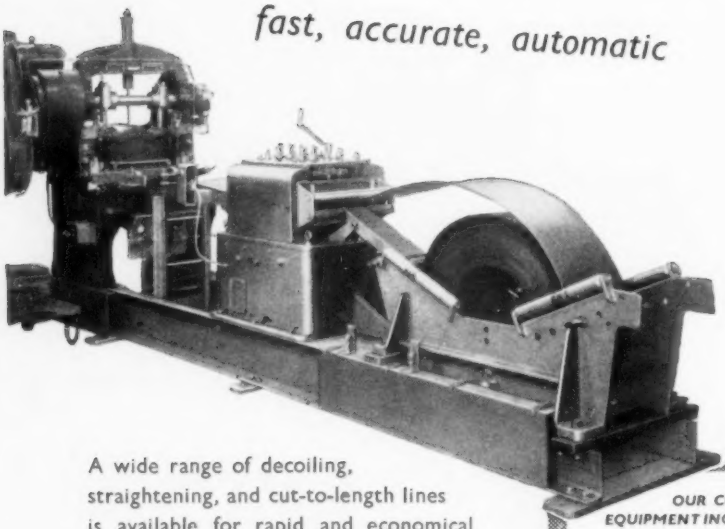

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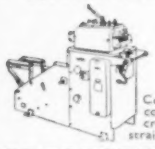

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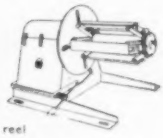
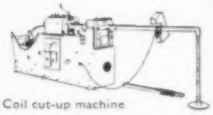


Coil reel



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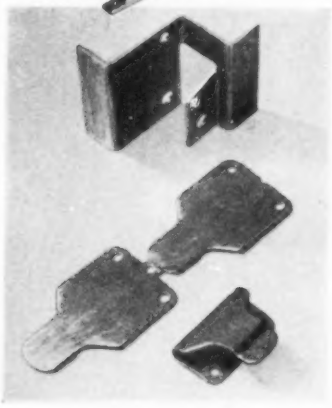

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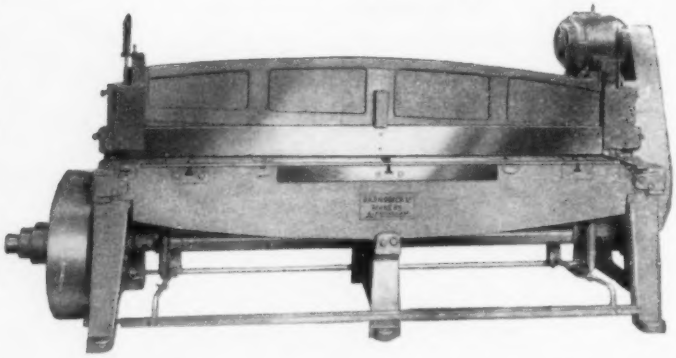

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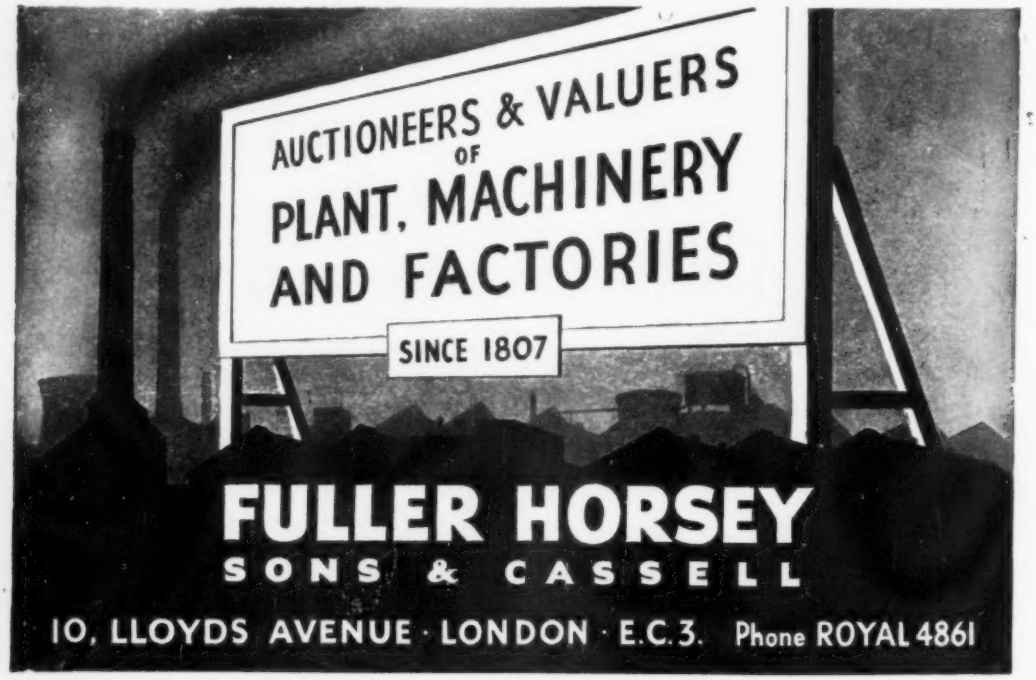

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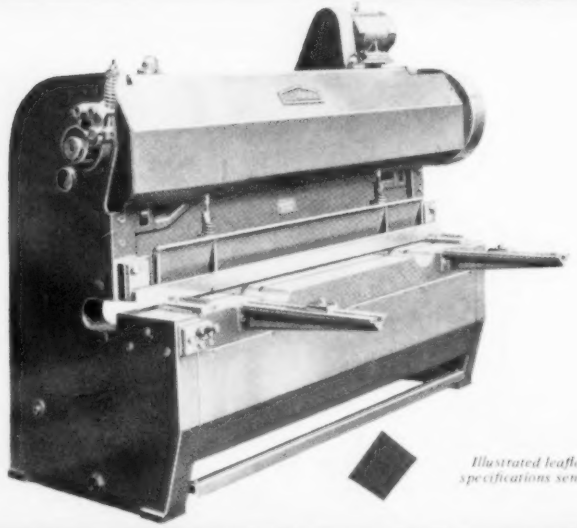

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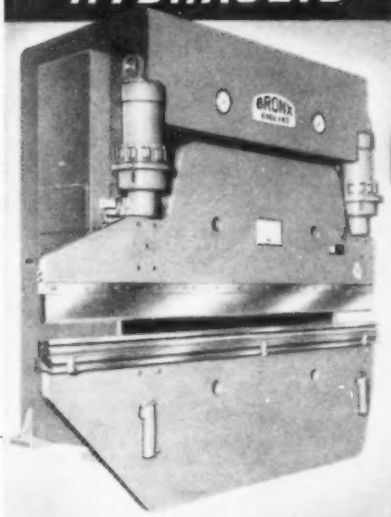

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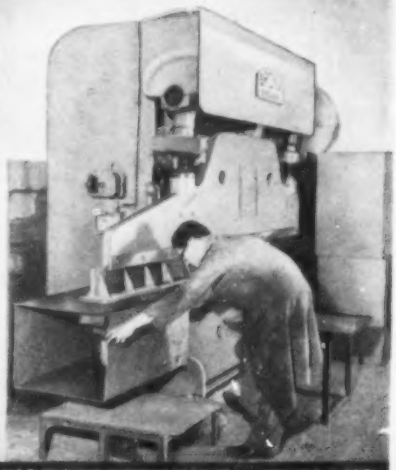

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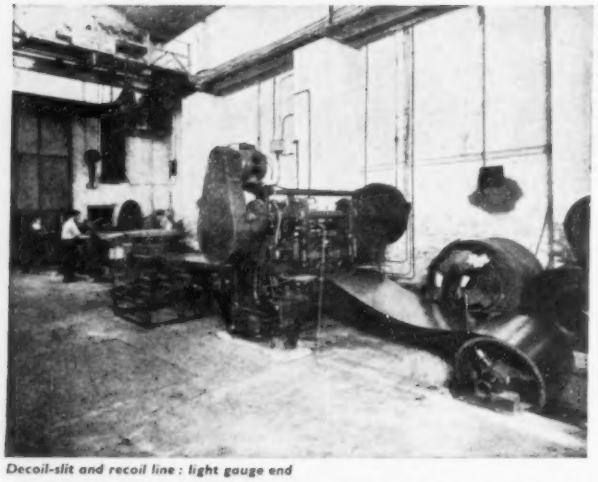

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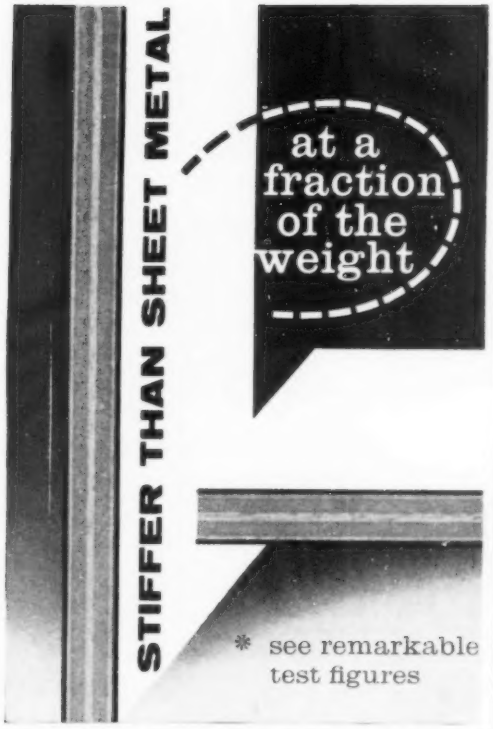

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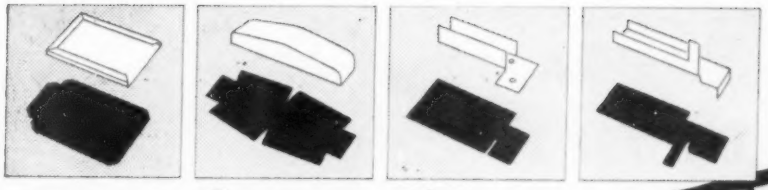

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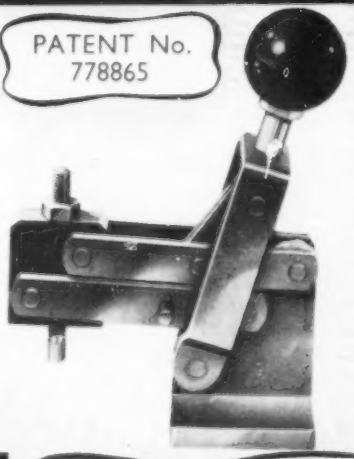

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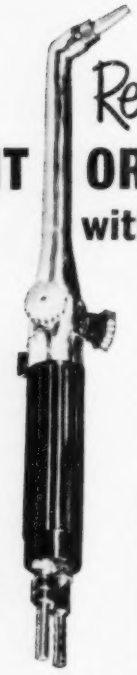

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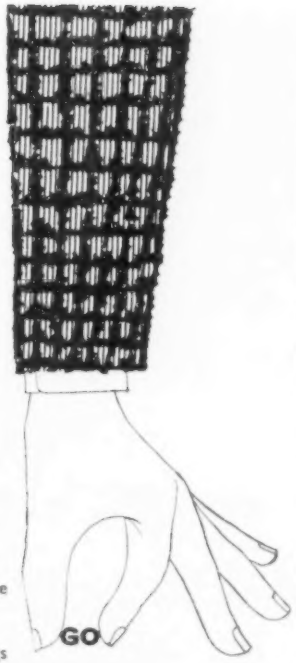

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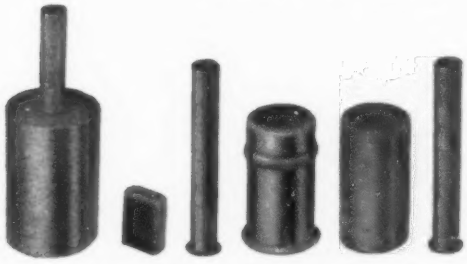

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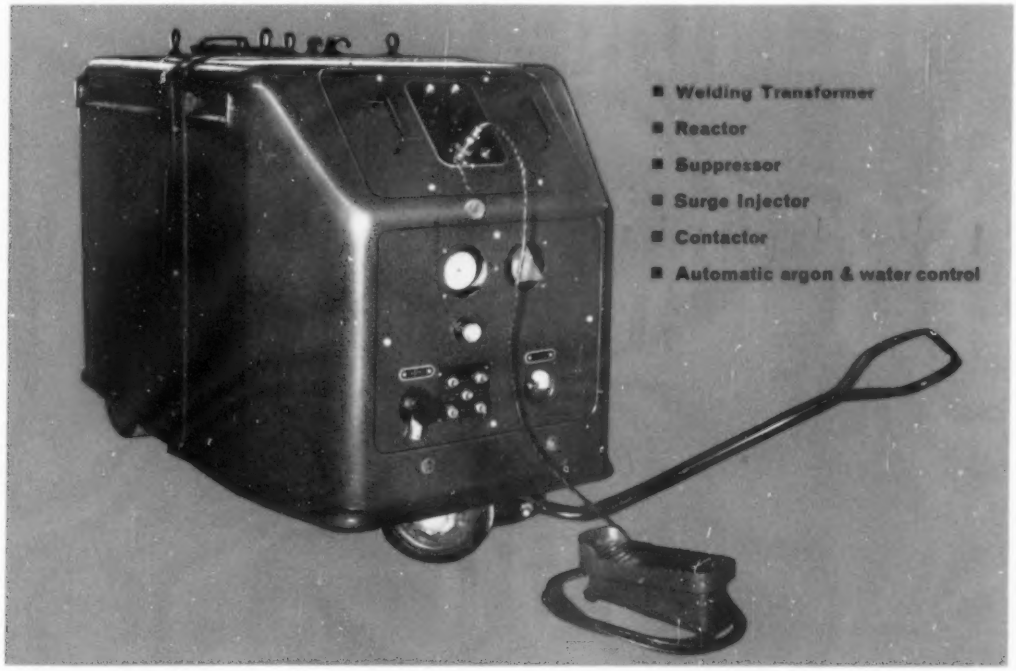

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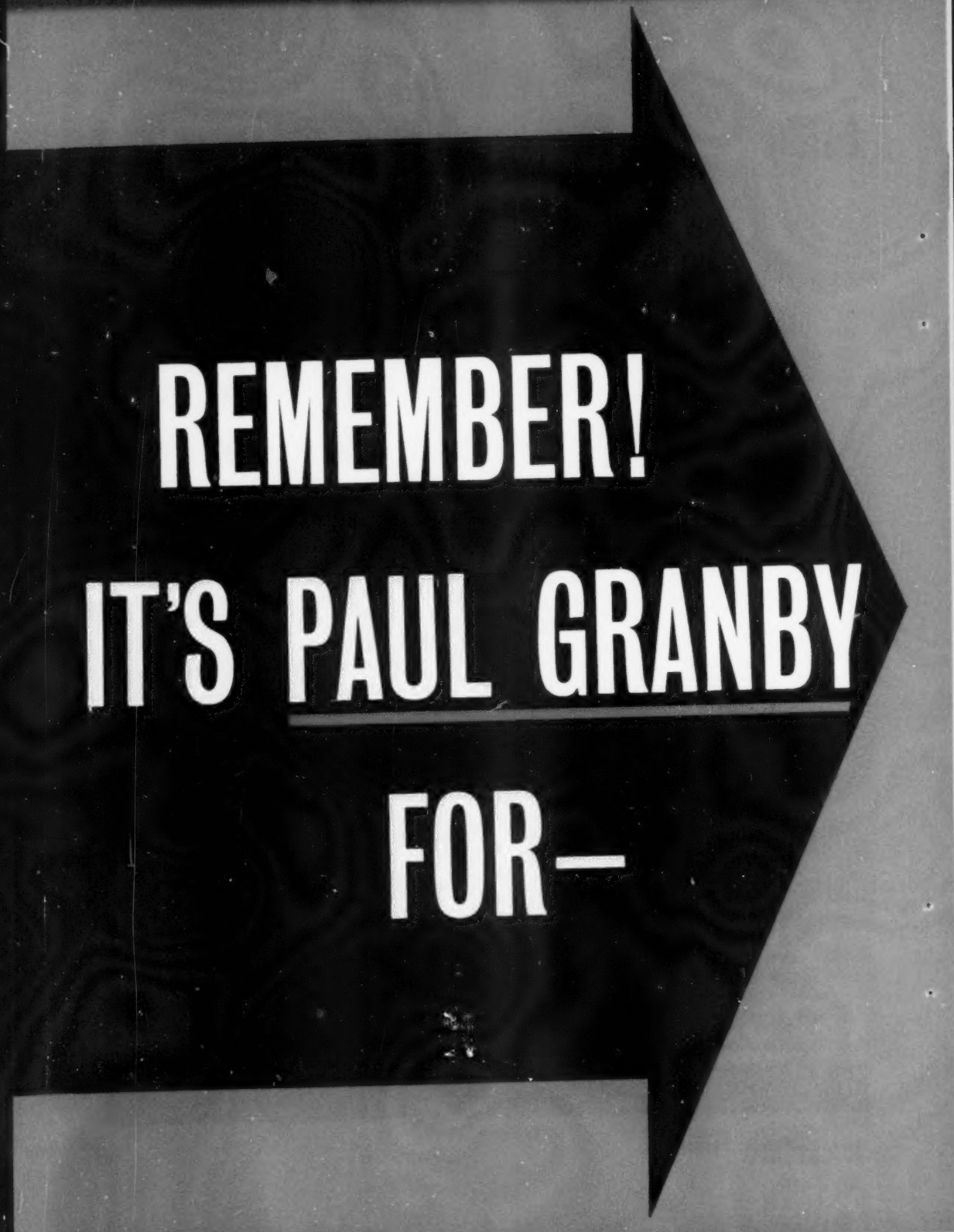
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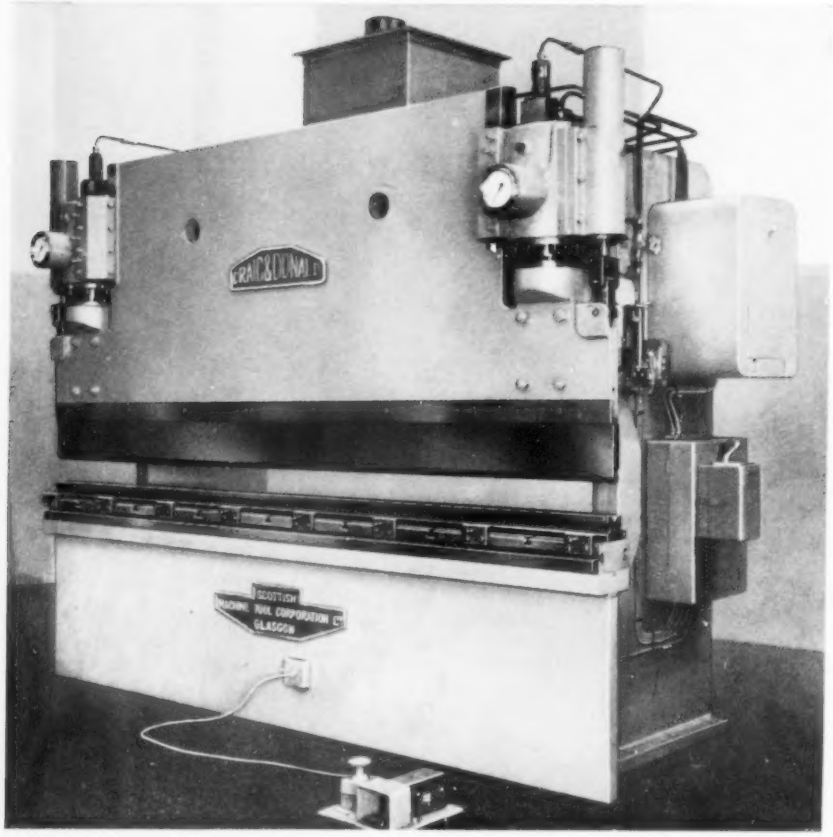

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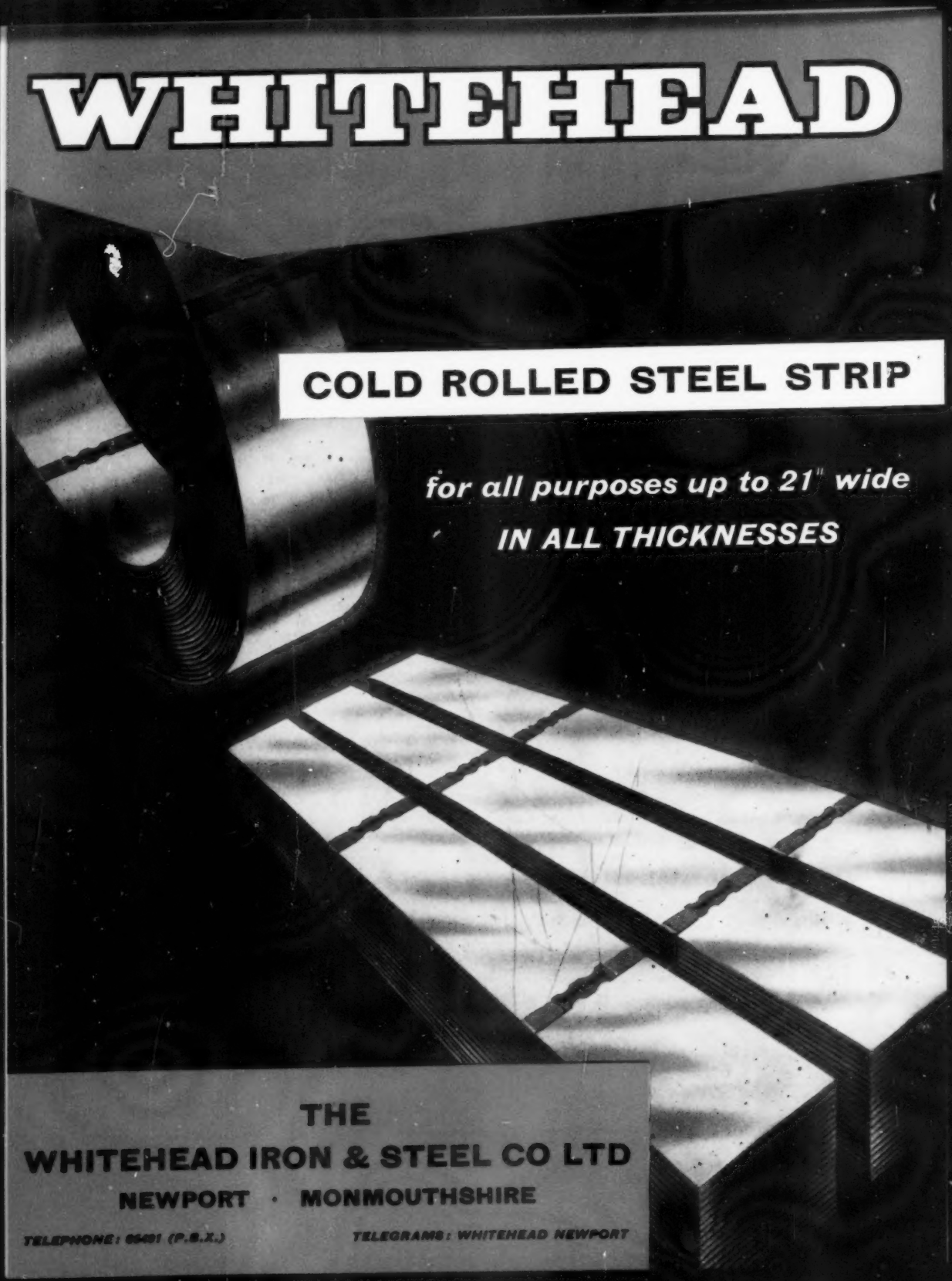

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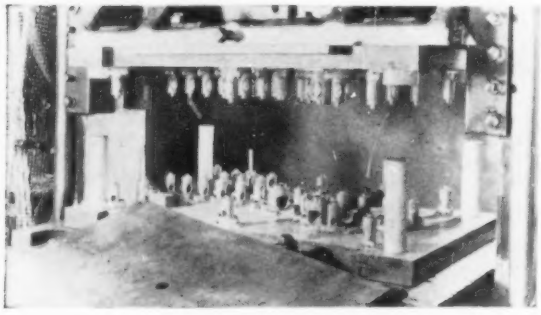

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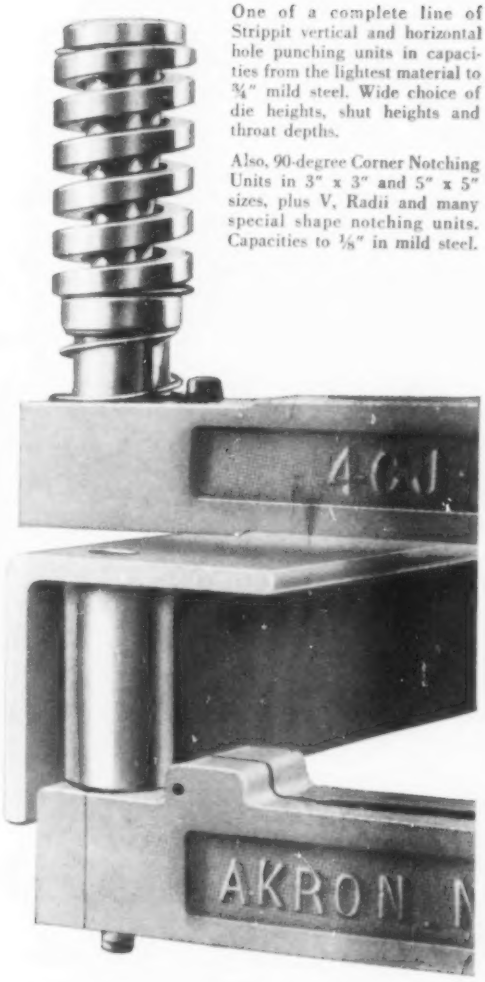

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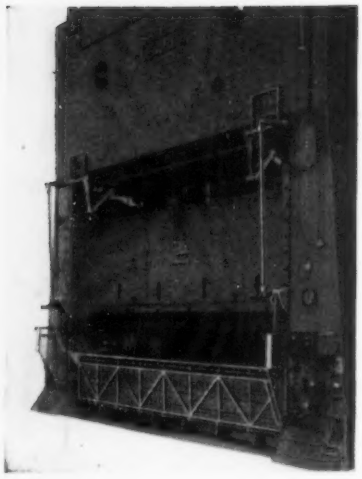

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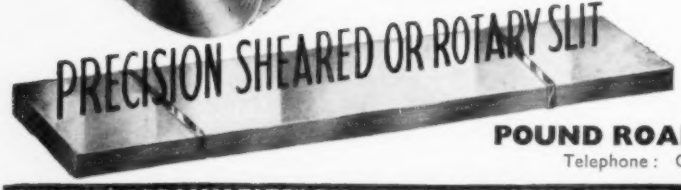

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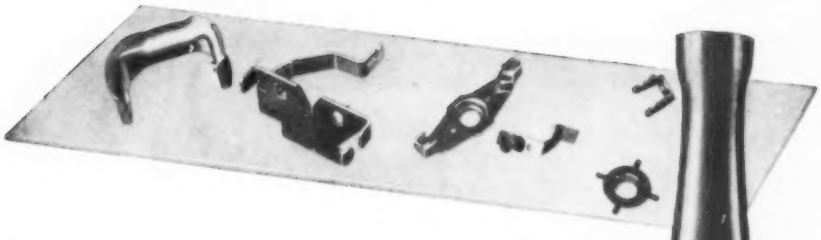

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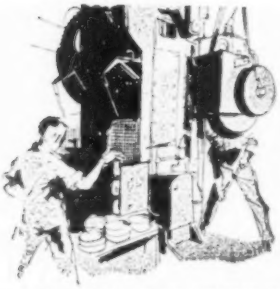

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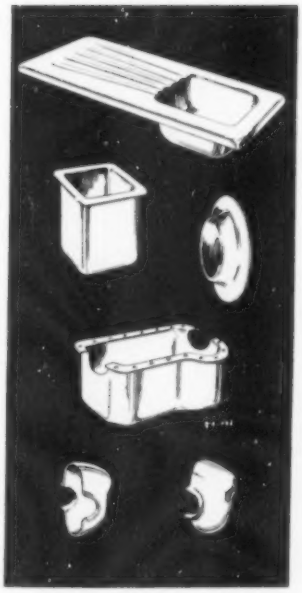

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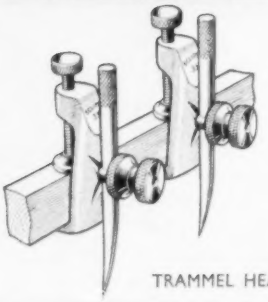

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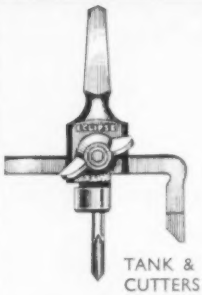

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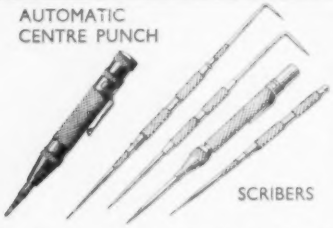

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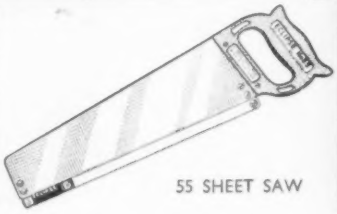

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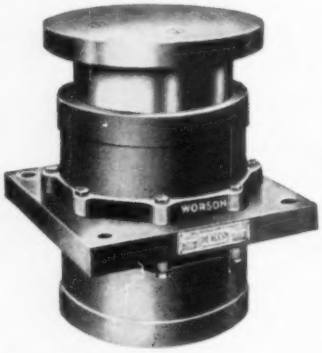

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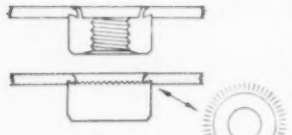

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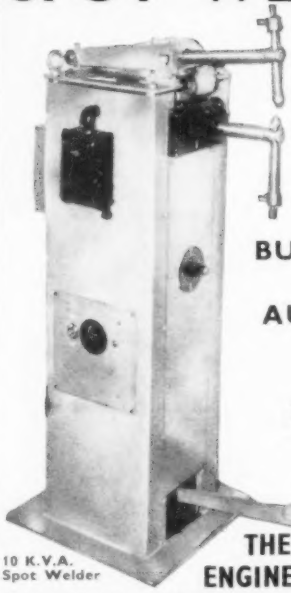

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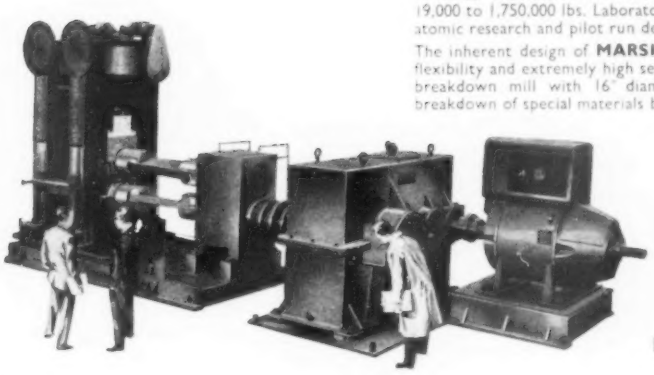

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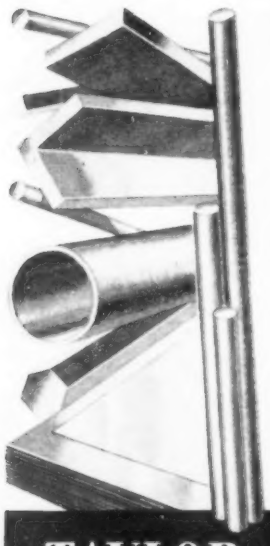

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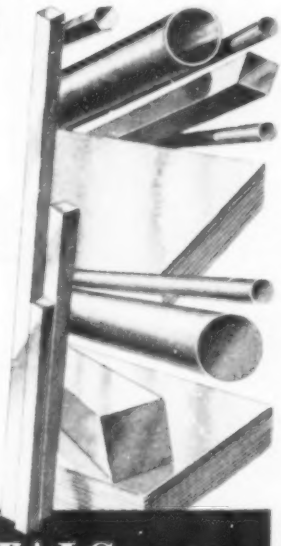

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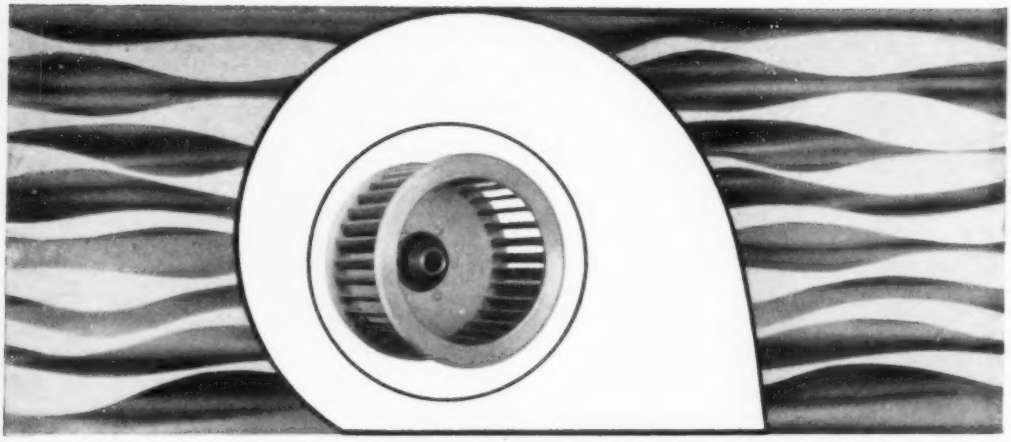

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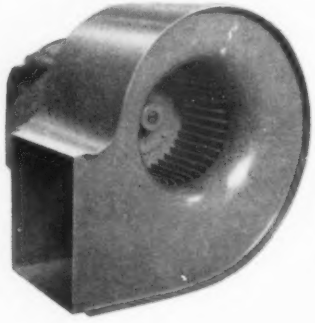

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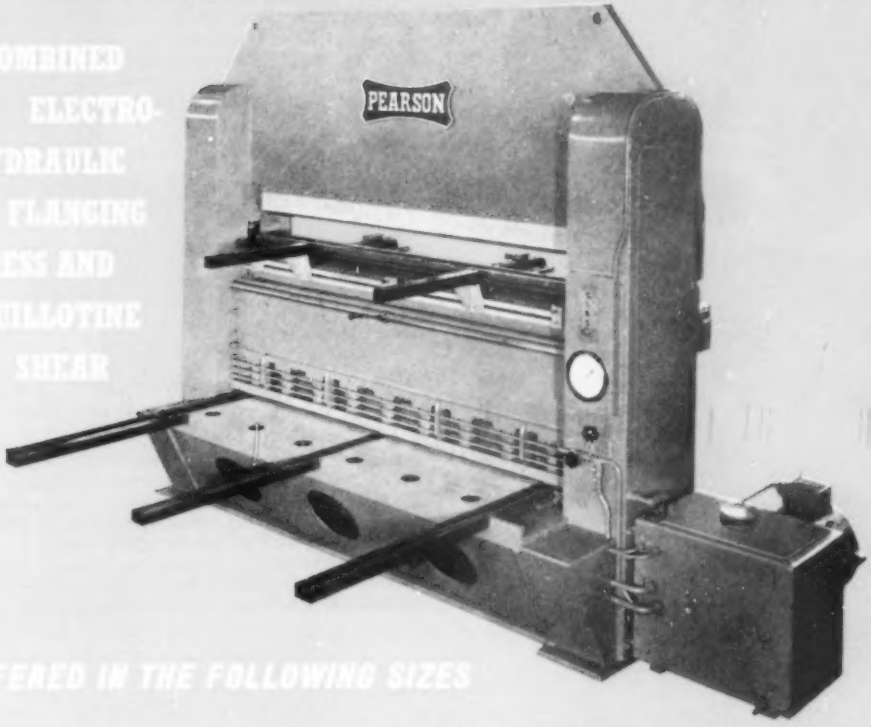

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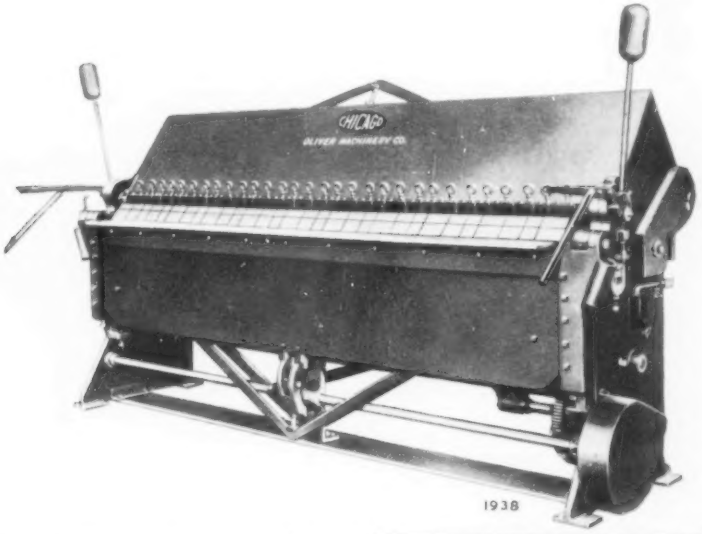

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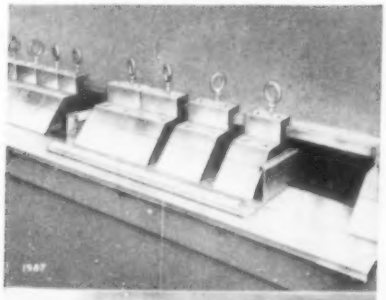

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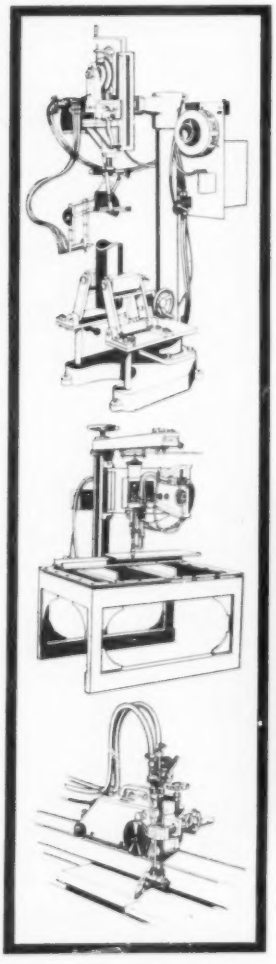

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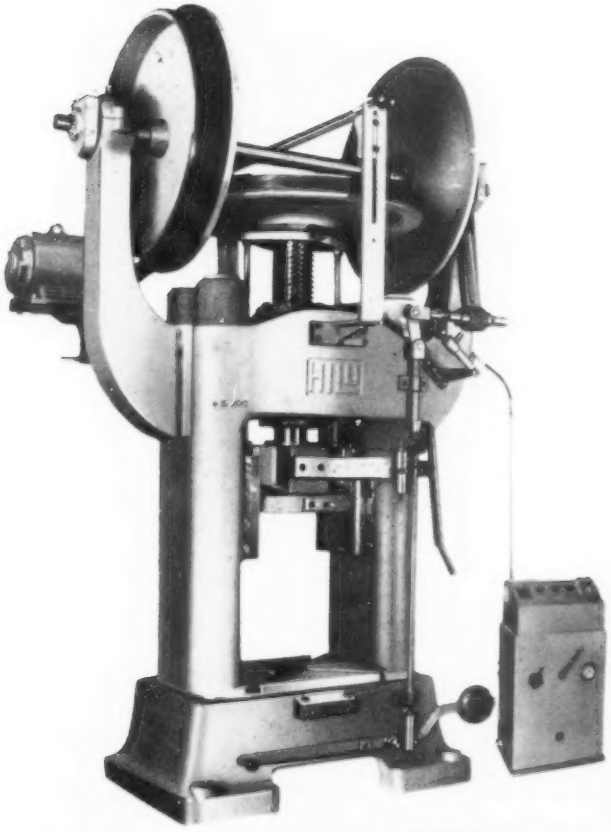

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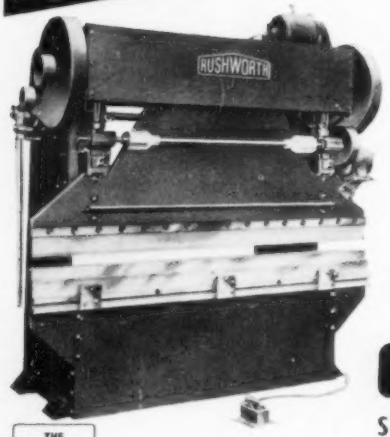

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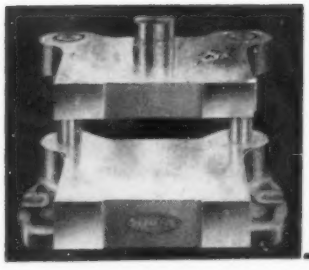

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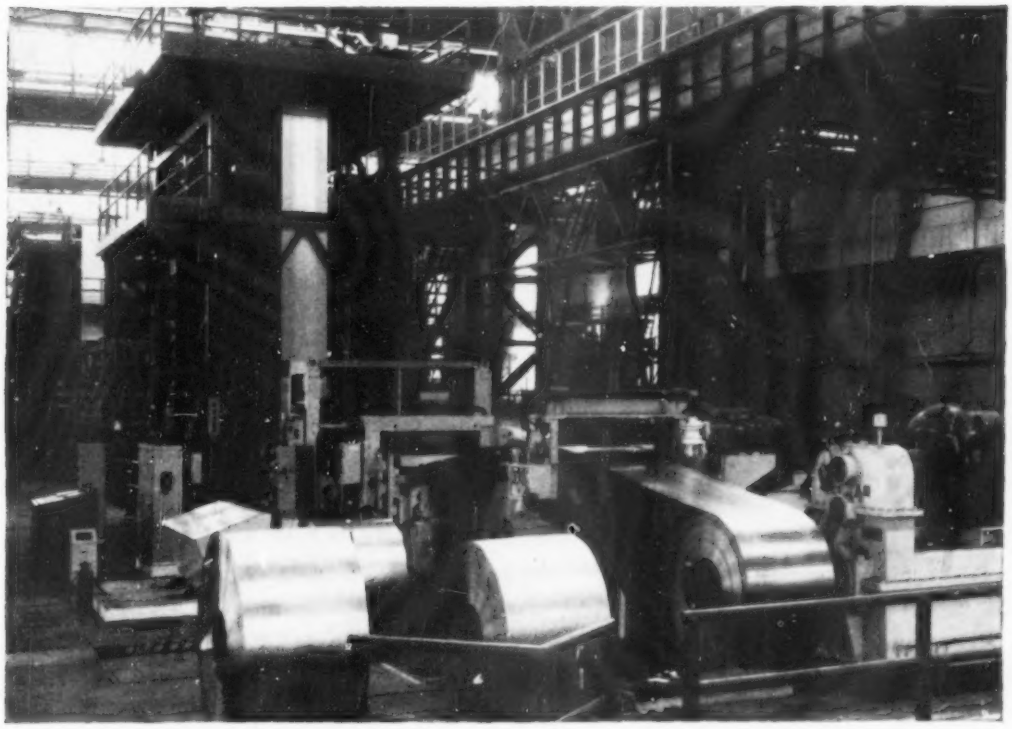

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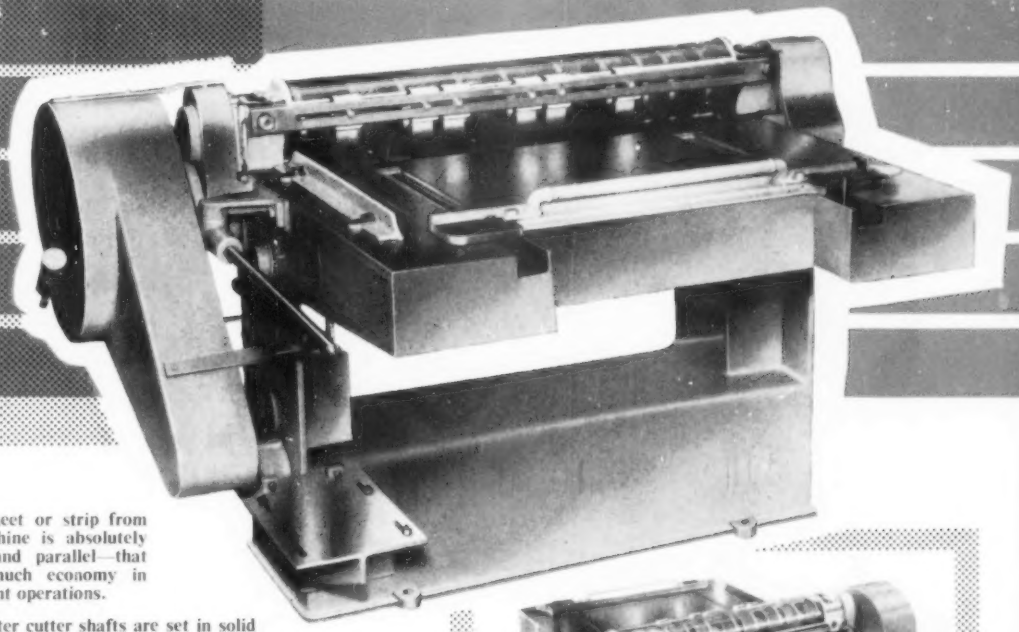

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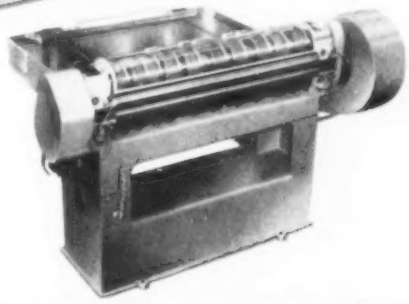

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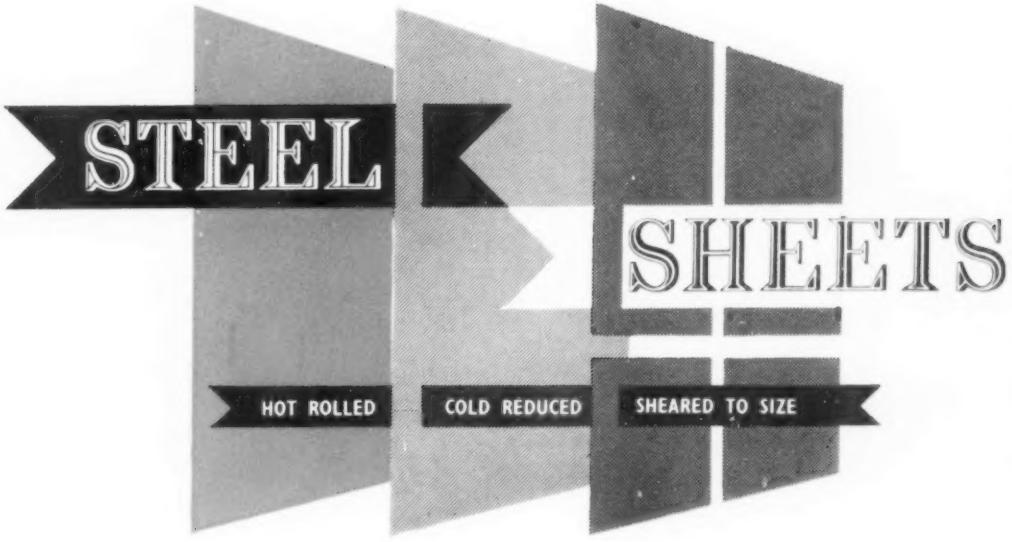

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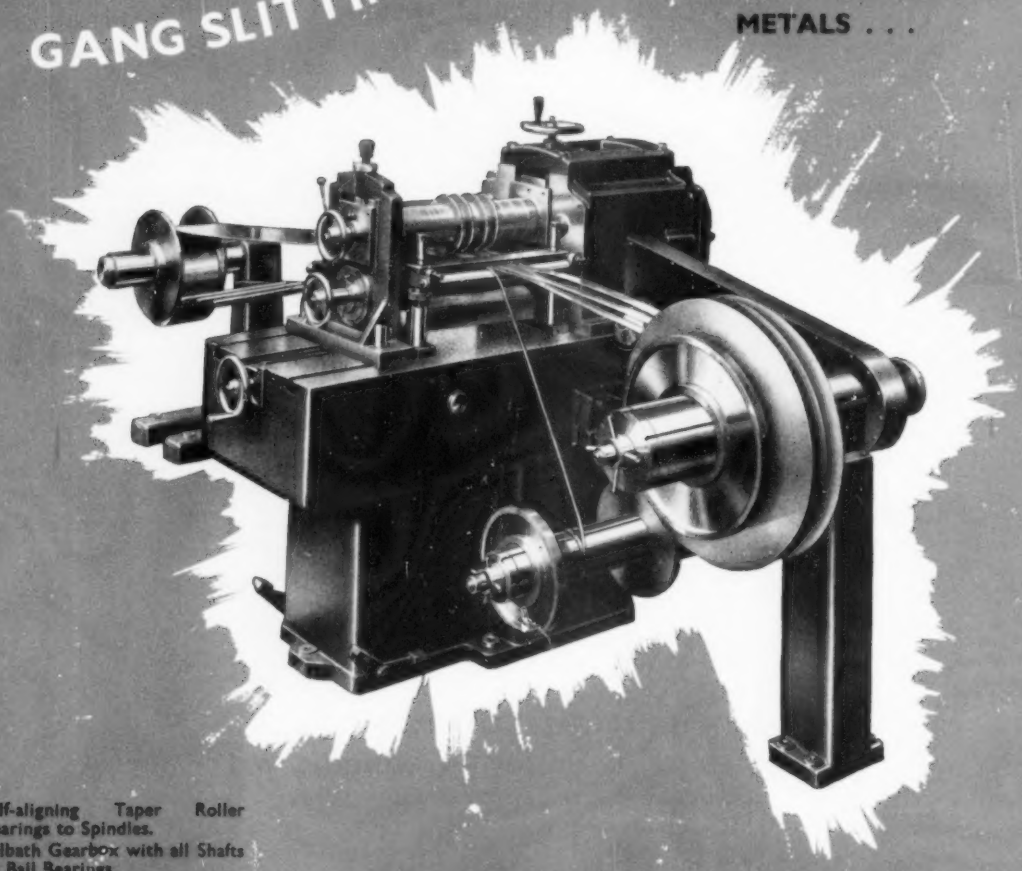

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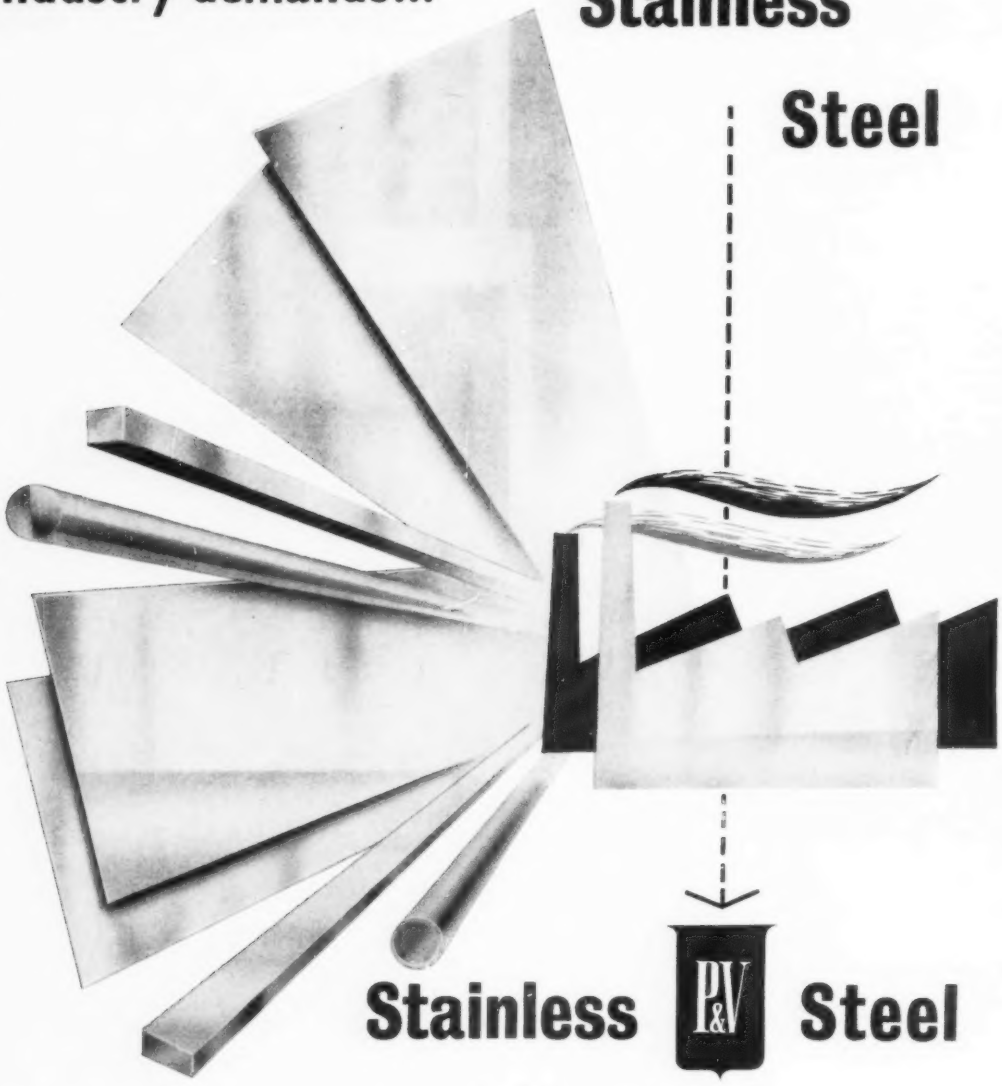

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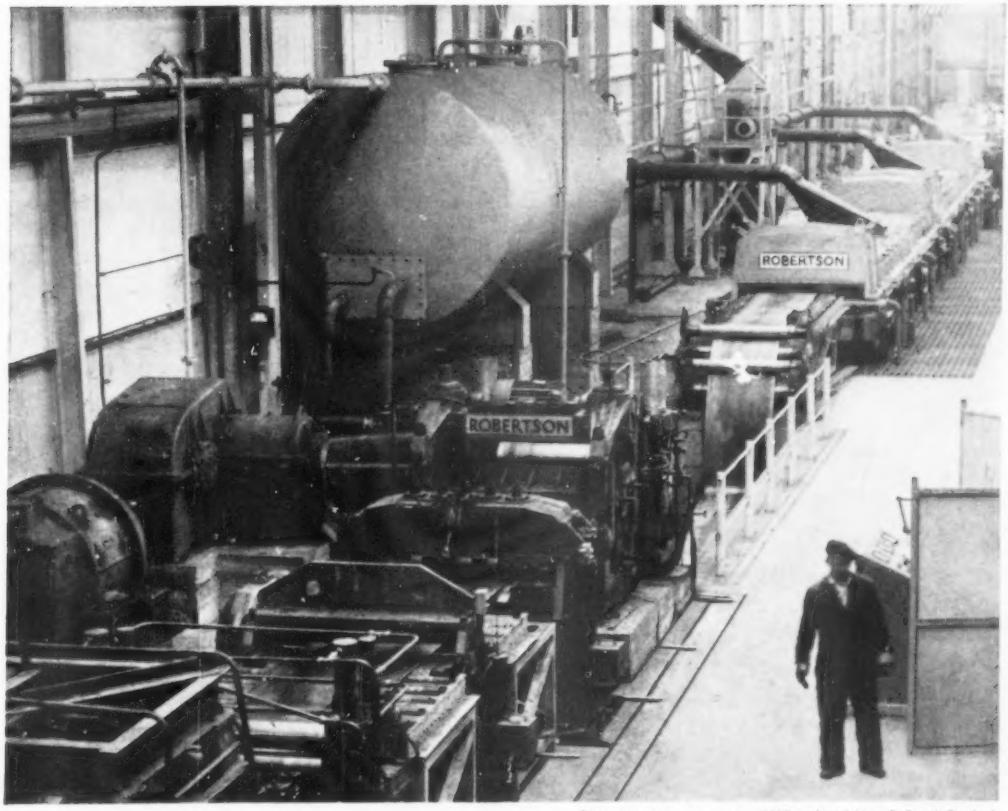

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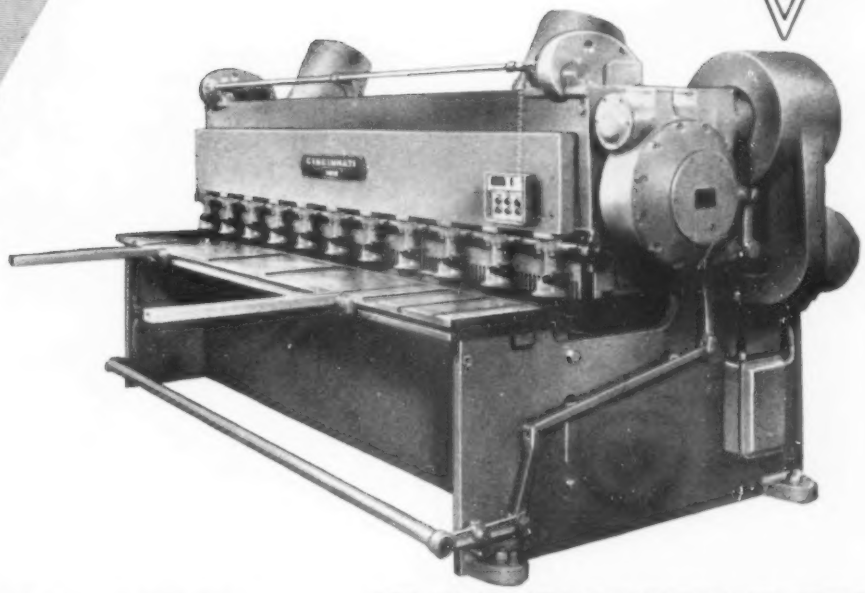

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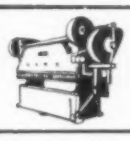

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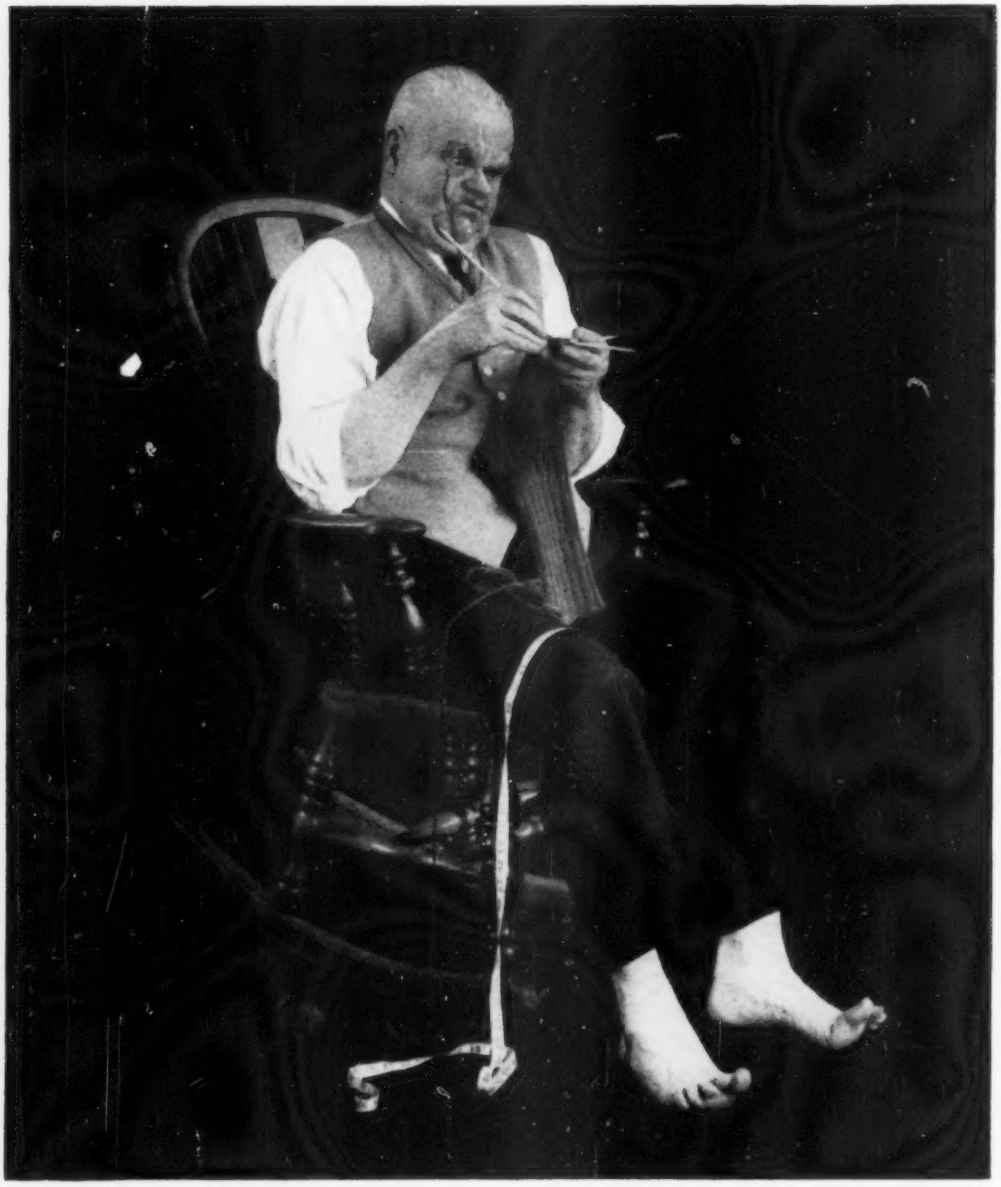

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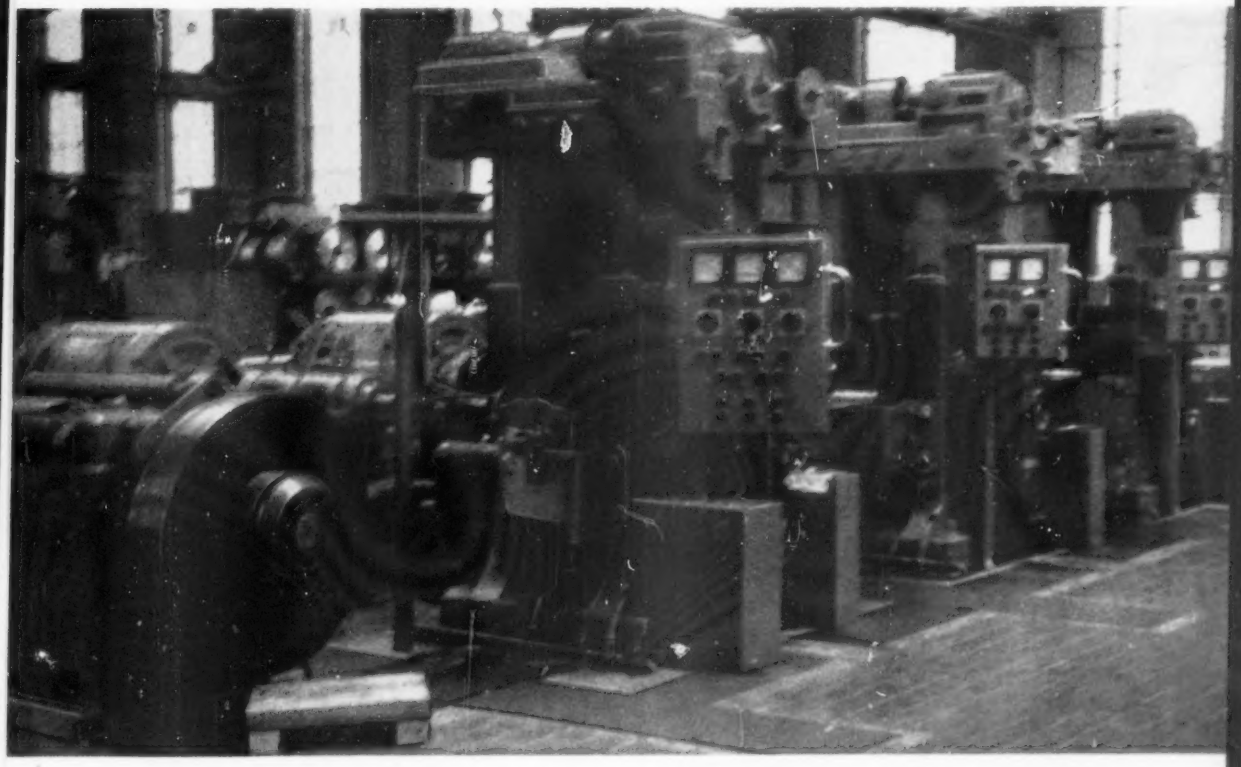

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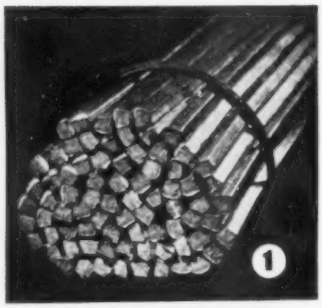

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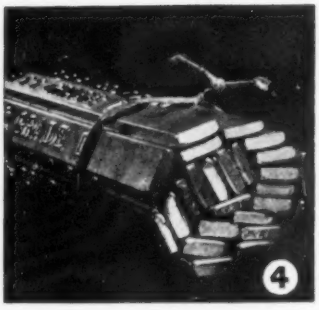

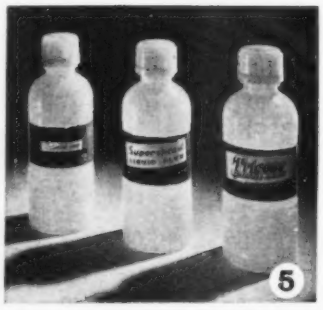

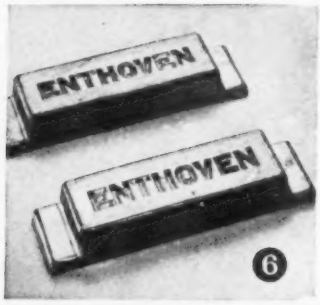

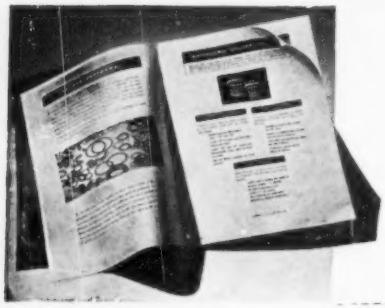

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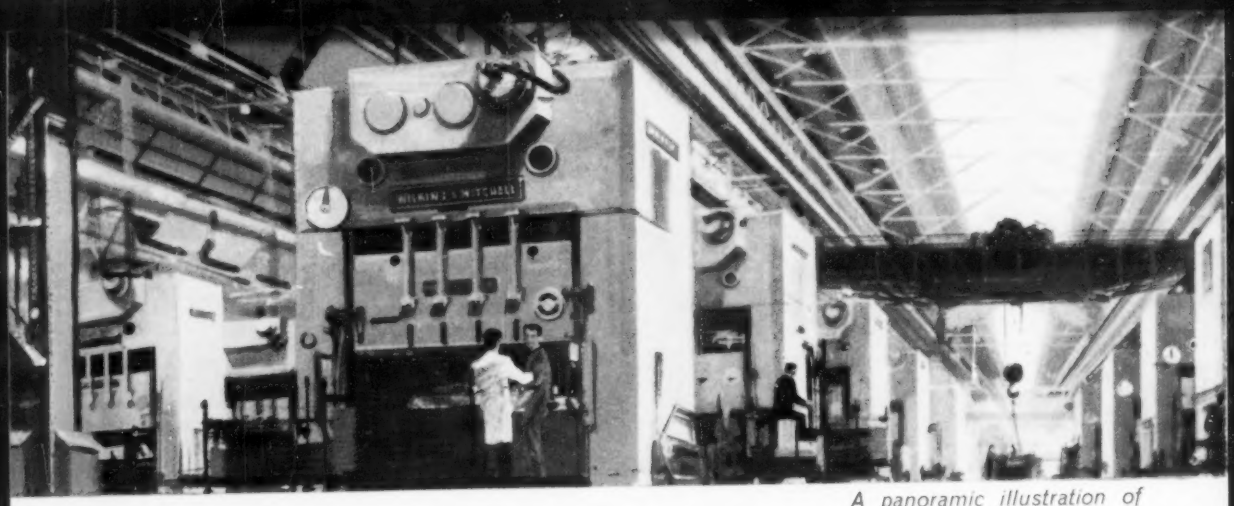
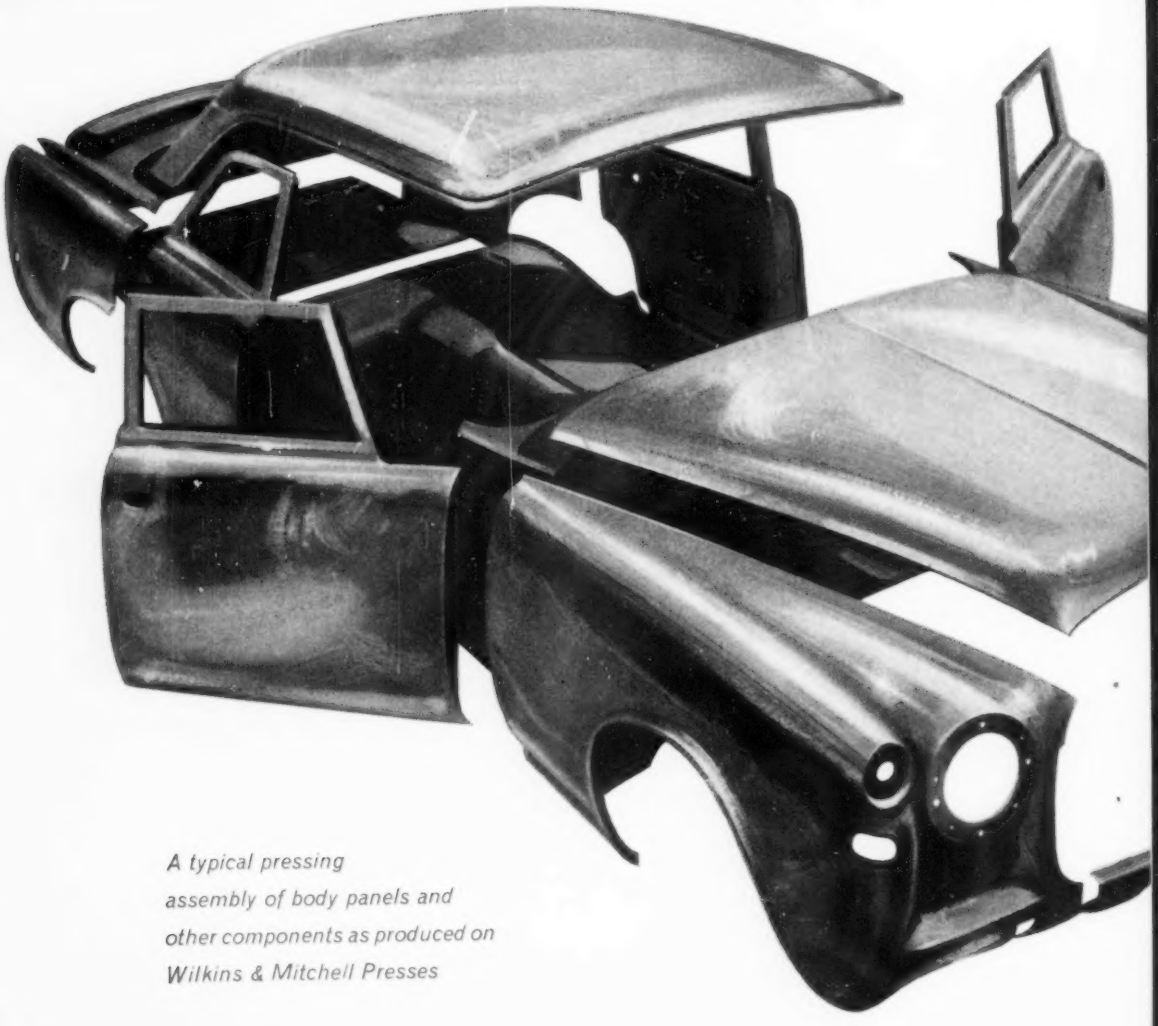
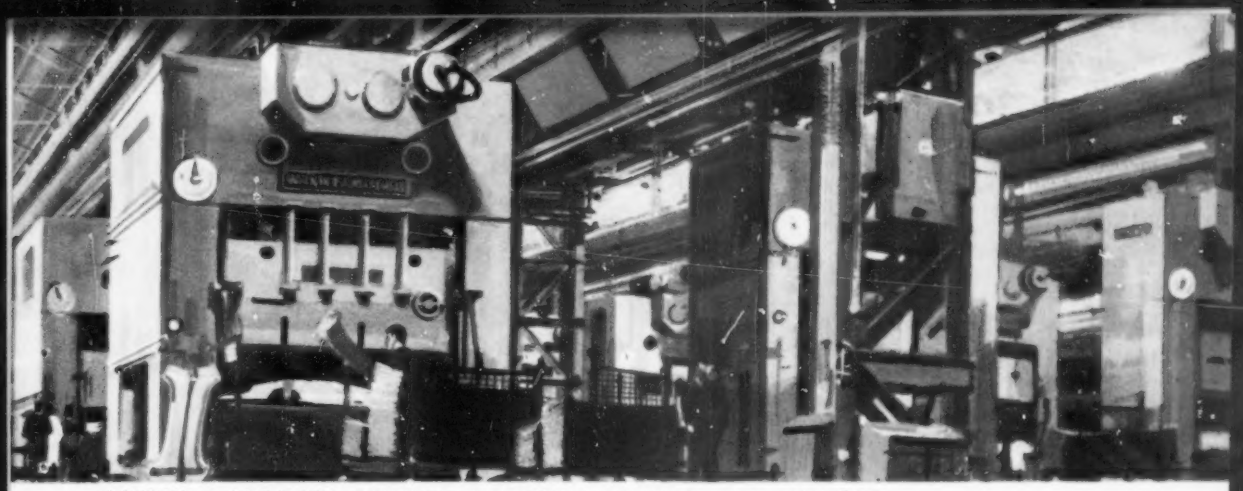


A panoramic illustration of



A typical pressing
assembly of body panels and
other components as produced on
Wilkins & Mitchell Presses



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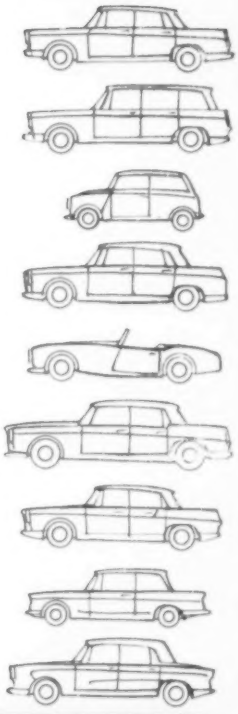

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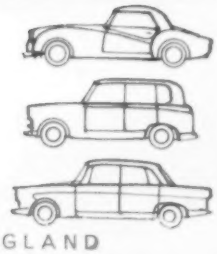

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The Importance of the Steel Stockholder .. 786

John Annetts

The author of this comment is the Chairman of the National Association of Iron and Steel Stockholders.

Investigations on the Swift Cupping Test .. 787

J. H. Zaat, phys.drs.

On the basis of a theoretical discussion and experimental data it is shown that it is possible to carry out the cupping test in such a manner that, independently of sheet thickness and punch diameter, only the steel properties occur as variables. In this connexion specific requirements are described which must be satisfied by testing equipment and testing conditions. The definition for Limiting Drawing Ratio (LDR) is amended. Thus it is possible to perform the cupping test more accurately than previously, but the disadvantage is that specialized tools and accurate apparatus are required.

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A. Reeves

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Quantitative Assessment of Deep-Drawing and Stretch-Forming Qualities—3 813

J. C. Wright, B.Sc., Ph.D., A.I.M., A.C.T. (Birm.)

In this, the third and concluding instalment of his article, the author considers the correlation of non-simulative test results with industrial press results, the correlation of simulative test results with industrial press results, deals with the correlation of both types of test results with each other and gives information on the effect of strain-ageing on test results.

A Mechanized Press Line for Producing External Door Panels of the GAZ-51 Automobile 825

N. P. Yashnov, V. V. Kolobov and G. V. Grekov

This line consists of a guillotine shear, various roller conveyors and four heavy presses. Various loading and unloading devices are incorporated in the line, and one set of tools incorporates what are called "floating shears."

Economic Tooling for Batch Production .. 829

Norman Ford

Some examples of multi-stage tooling in use at the works of James H. Randall and Sons Ltd.

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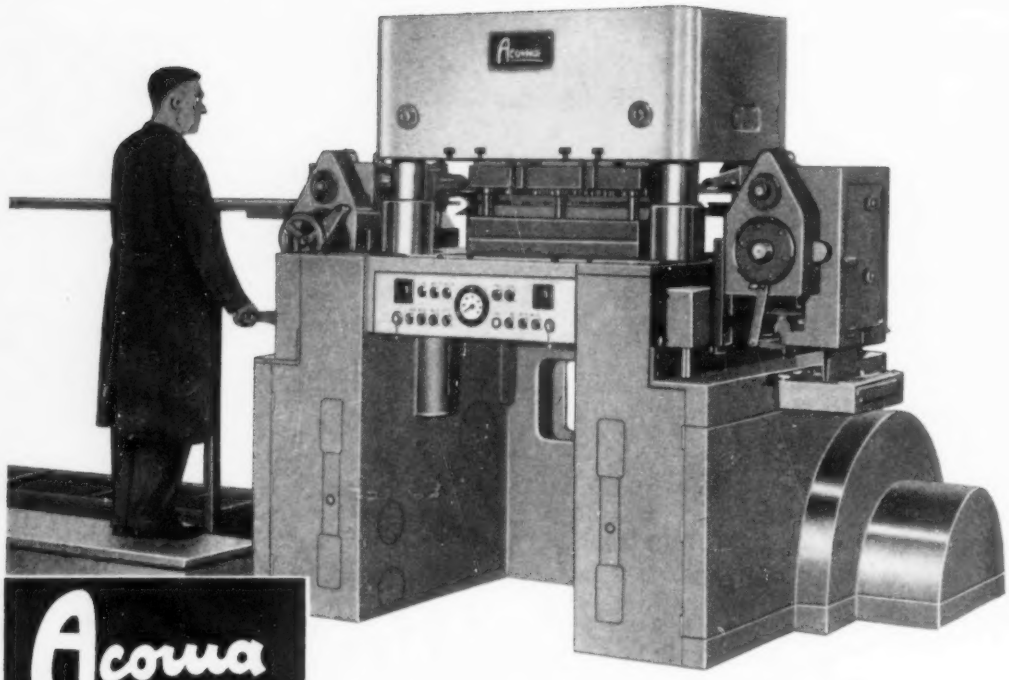

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Fixed stroke, (alternatives)	472	630	787	787	984	984	1 260	1 260
	630	787	984	984	1 260	1 260	1 496	1 575
	709"	945"	1 181"	1 339"	1 496"	1 496"	1 654"	1 890"
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Maximum width of stock	3½"	4½"	7"	9½"	9½"	9½"	9½"	12½"
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FOR OUR OVERSEAS READERS

RÉSUMÉS DES PRINCIPAUX ARTICLES

Enquête sur le Test de Swift d'emboutissage de cuvettes page 787

Par J. H. Zaat, phys. drs.

Sur la base d'un argument théorique et de renseignements expérimentaux, il est démontré qu'il est possible d'effectuer un essai d'emboutissage de cuvettes de telle sorte que, indépendamment de l'épaisseur de la tôle et du diamètre du poinçon, seules les propriétés de l'acier représentent des variables. A ce propos, l'auteur décrit les exigences spécifiques que doivent satisfaire les appareils d'essai et les conditions du test. La définition de la limite du rapport d'emboutissage (Limiting Drawing Ratio (LDR)) est modifiée. Ainsi il est possible de réaliser l'essai d'emboutissage de cuvettes avec plus de précisions que par le passé, mais, par contre, avec le désavantage d'avoir à s'équiper d'outils spéciaux et d'appareils de précision.

Evaluation quantitative de l'emboutissage profond et du façonnage à la presse par allongement .. page 813

Par J. C. Wright, B.Sc., Ph.D., A.I.M., A.C.T. (Birm.)

Dans ce fascicule, le troisième et dernier de son article, l'auteur considère la corrélation des résultats d'essais non-simulateurs avec les résultats obtenus par les presses industrielles, la corrélation des résultats d'essais simulateurs avec les résultats obtenus par les presses industrielles, traite de la corrélation des résultats des deux types d'essais l'un avec l'autre et donne des renseignements sur les effets du vieillissement causé par les efforts de flexion sur les résultats des essais.

Chaîne mécanique d'emboutissage pour la fabrication des panneaux extérieurs de portières de la voiture GAZ-51 .. .. .. page 825

Par N. P. Yashnov, V. V. Kolobov et G. V. Grekov.

La chaîne comprend une cisaille à guillotine, certains transporteurs à rouleaux et quatre presses lourdes. Différents appareils de chargement et de déchargement sont compris dans la chaîne tandis que des appareils nommés "cisailles flottantes" font partie d'un jeu de machines-outils.

ZUSAMMENFASSUNGEN DER HAUPTARTIKEL

Untersuchungen zum Swift-Prüfbecherversuch Seite 787

Von J. H. Zaat, phys. drs.

An Hand von theoretischen Erwägungen und experimentellen Daten wird gezeigt, daß sich der Becherversuch so ausführen läßt, daß Blechdicke und Dorndurchmesser nicht eingehen und nur die Eigenschaften des Stahls als Veränderliche auftreten. In diesem Zusammenhang werden die besonderen Forderungen beschrieben, die von der Prüfeinrichtung und den Prüfbedingungen einzuhalten sind. Die Definition des Grenz-Ziehverhältnisses wird revidiert. Auf diese Weise wird es möglich, den Becherversuch genauer zu machen als bisher; der Nachteil ist jedoch, daß besondere Werkzeuge und ein präziser Apparat benötigt werden.

Quantitative Abschätzung von Tiefzieh- und Streckformeigenschaften—3 .. Seite 813

Von J. C. Wright, B.Sc., Ph.D., A.I.M., A.C.T. (Birm.)

In diesem dritten und letzten Teil seines Artikels behandelt der Verfasser die Beziehung der Ergebnisse von nichtsimulativen und simulativen Versuchen zu den Ergebnissen an industriellen Pressen und zueinander. Es werden Angaben über den Einfluß der Reckalterung auf die Versuchsergebnisse gemacht.

Eine mechanisierte Pressenstraße zur Herstellung der äußeren Türverkleidungen des Kraftwagens GAZ-51. Seite 825

Von N. P. Yashnov, V. V. Kolobov und G. V. Grekov.

Die Straße besteht aus einer Tafelblechschere mit Kurbelantrieb, mehreren Rollenbahnen und vierschweren Pressen. Sie ist mit verschiedenen Lade- und Entladevorrichtungen ausgerüstet, und ein Werkzeugsatz enthält sog. „schwebende Scheren".

RÉSUMENES DE LOS ARTICULOS PRINCIPALES

Investigaciones sobre el ensayo Swift de acopamiento. página 787

Por J. H. Zaat, phys. drs.

A base de una discusión teorética y de datos experimentales se demuestra que es posible llevar a cabo el ensayo de acopamiento de forma tal que, independientemente del espesor de la chapa y del diámetro del troquel, solamente aparecen como variables las propiedades del acero. En este sentido se describen las exigencias específicas que han de satisfacer el equipo de ensayo y condiciones de ensayo. Se modifica la definición de la Relación Limitadora de Estiramiento (LDR). Así resulta posible llevar a cabo el ensayo de acopamiento con mayor precisión que anteriormente, pero se tiene la desventaja de que precisan herramientas especiales y aparatos de precisión.

Evaluación cuantitativa de las cualidades para el estampado profundo y el estiramiento—3 página 813

Por J. C. Wright, B.Sc., Ph.D., A.I.M., A.C.T. (Birm.)

En esta la tercera y última parte de su artículo, el autor estudia la correlación de resultados de ensayos no simulativos con los resultados de prensas industriales, la correlación de resultados de ensayos simulativos con los de prensas industriales, trata de la correlación de ambos tipos de resultados de ensayos el uno con el otro y da información sobre el efecto del envejecimiento por esfuerzo sobre los resultados de los ensayos.

Una cadena de prensa mecanizada para la producción de los paneles exteriores de las puertas del automóvil GAZ—51. .. página 825

Por N. P. Yashnov, V. V. Kolobov y G. V. Grekov.

Esta cadena de producción se compone de una cizalla de guillotina, varios transportadores de rodillos y cuatro grandes prensas. La cadena está también dotada de diversos dispositivos de carga y descarga y un juego de herramientas comprende lo que llaman "cizallas flotantes".

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"FOR too long, sections of British industry have been becoming increasingly insular, introspective, restrictive, reactionary, and inflexible. The protection of sections of industry which are obsolete and inefficient and ought therefore to be shut down so that the manpower, including management, is available for more progressive and developing industry, has been matched on the trade union side with restrictive practices, arising largely from the demarcation of one union from another, which has made it exceedingly difficult for some enterprises to adopt more efficient methods of production".

We quote Mr. S. P. Chambers, chairman of Imperial Chemical Industries Ltd., in the course of an address to the Institute of Personnel Management recently. Mr. Chambers was speaking on some of the problems attendant upon Britain's proposed entry into the European Economic Community and we would not venture here to add further to the torrent of comment which has flowed in spate since the first announcement of the Government's intentions to open negotiations with the Six but there is one aspect of the British pattern of thought that does require airing at the present time.

It is a trait which stems directly from the insularity referred to in our opening paragraph and it manifests itself as an insistence on regarding a journey beyond the confines of these Island shores as being something of a very special nature only to be undertaken under very particular circumstances. A company in Portsmouth would hardly think twice about sending one of their representatives to Newcastle-on-Tyne if he wished to attend a technical meeting or visit a customer, but if he were to suggest making the journey in the opposite direction, across the Channel, it would immediately be assumed that he had conjured up some insubstantial reason for putting himself into a position to sample Parisian night life.

Large numbers of technical meetings of varying significance are held in various centres in Europe throughout the year which command a considerable attendance from most of the countries on the Continent, many of whose delegates have to travel greater distances than would those from the U.K. if they were to go. Admittedly the cost of travel is significant and languages do present a quite unwarrantable difficulty to the Anglo-Saxon but neither of these factors is the real one which operates to keep British participation in overseas technical discussions at a minimum.

On the occasions when British scientists and technologists do attend scientific or technical meetings held abroad they find them at least as valuable as equivalent meetings held at home, although all too often the full value is not reaped because of the well-known predilection of the Englishman abroad for associating only with his own fellow nationals.

It may possibly have been true a half-century ago that in an international technical interchange this country had more to give than to receive, but such is certainly not the case today and the virtues of full technical discussion to which the Memoranda of our technical institutes bear such effective testimony shine just as brightly in "furrin' parts".

THE IMPORTANCE OF THE STEEL STOCKHOLDER

By JOHN ANNETTS*

Further to the comment from a steel producer on the role of the steel stockholder published last month the Chairman of the National Association of Iron and Steel Stockholders adds his views from the point of view of the stockholders themselves.

FOR many years, the steel stockholders' role in the distribution of steel has been recognized as an important one. That importance is growing, for a great many reasons.

The modern steelmaker, for reasons of production efficiency, is able to supply rollings to particular sizes only in appreciable tonnages. The modern steel user can often only buy in such substantial quantities at considerable risk of loss. Between the two, there is a gap which only the steel stockholder can fill.

Advantages for the Steel User

By placing greater reliance on the steel stockholder, the steel user can keep his stocks at a reasonable level. Capital is no longer "tied-up" for months. Risks of loss through such factors as obsolescence and deterioration are substantially reduced. Storage and handling costs are cut to a minimum.

The stockholder has the range to enable requirements to be met promptly, no matter how swiftly they alter. This is an increasingly important point in these days of frequent changes in product design.

The steel stockholder service, geared as it has always been to supply urgent requirements fast, is able to deliver steel when, where and *as* it is wanted—generally at very short notice indeed.

The stockholders' cutting equipment is always at the service of the user.

A Flow of Steel

Finally—and this, perhaps, is the most significant factor of all—the stockholder service enables a steel user to replace spasmodic ordering with a planned and realistic flow of steel, gauged to his precise production requirements. This is the surest way to secure full continuity of production, whatever the circumstances.

The Financial Side

Perhaps the most frequently encountered argument *against* the use of the steel stockholder service is the question of *first* cost ; but the apparent saving in first cost effected by buying direct from the steelmaker disappears on detailed examination, especially where the stocks bought are seriously in excess of current requirement, and thus become "dead steel".

The factors already mentioned — "tied-up" capital, storage and handling costs, cost of space, deterioration plus the additional risk of obsolescence—often raise the true cost of steel to a cost-figure 20 per cent or more above the maker's price.

The stockholder service, when used intelligently as part of a user's plan for maintaining a flow of steel, will represent a very substantial saving.

The Stockholder and the Steelmaker

Another opinion often expressed by the steel user is that there exists a danger in that he may lose a priority position *on the maker's list* through ordering from a stockholder. It should be emphasized that the stockholder is basically offering a supplement to the steelmaker's service of the very goods that the steelmaker produces—a supplement which is as much in the interest of the maker as it is of the steel user. This becomes clear as soon as the situation is looked at on a national level.

The Fluctuation Problem

It is now widely acknowledged that the incessant fluctuations in steel "supply and demand" market conditions, that have been so marked a characteristic of the steel industry in recent years, are to a very large extent both artificial and unnecessary.

Heavy Over-Stocking

Over-stocking, when the tempo of production increases—which in Britain alone amounted to some 1,500,000 tons during the "boom" period of 1955-57, and reached the figure of 1,400,000 tons again last year—intensifies the pressure on the steelmakers to the point where actual artificial shortages are created, and production "slow-downs" in the steel user's factory follow as an inevitable consequence.

Some idea of the magnitude of this problem can be gained from the fact that, according to a recent estimate, Britain's balance of payments suffered by as much as £50,000,000 as a direct result of over-stocking in steel.

It is, therefore, in the interest of the steel user,

(*Continued in page* 803)

*Mr. Annetts is Chairman of the National Association of Iron and Steel Stockholders.

Some Investigations on the

SWIFT CUPPING TEST*

By J. H. ZAAT, Phys.drs.

Summary

On the basis of a theoretical discussion and experimental data it is shown that it is possible to carry out the cupping test in such a manner that, independently of sheet thickness and punch diameter, only the sheet properties occur as variables. In this connexion specific requirements are described which must be satisfied by testing equipment and testing conditions. The definition for Limiting Drawing Ratio (LDR) is amended. Hence it is possible to perform the cupping test, better than before, for testing deep-drawing material. The disadvantage is that many tools, as well as accurate apparatus, are required.

1. Introduction

THE research for a reliable testing method aimed at a comparative determination of the deep-drawing quality of sheet-material is not of recent date. The cup-forming test, in which from a circular blank a cup is drawn, is already some 30 years old. With the aid of tools, testing conditions and the definition of the limiting drawing ratio (LDR) so far applied, a reliable differentiation of the types of sheet could not be obtained, due to the fact that the results of this test do not only depend on the sheet properties but also on the tools and testing conditions.

If a sheet is drawn, using punches of increasing diameter the LDR *de*creases if the blankholder *pressure* is kept constant, whereas the LDR *in*creases if the blankholder *load* is kept constant. In order to make the evaluation independent of the punch-diameter the flange load has to be chosen differently. The same applies to the influence of the sheet-thickness as is also found when the Erichsen test is performed. This is caused by the fact that the tools and testing conditions are not adapted to the modified sheet thickness.

So as to render the test suitable for the determination of the sheet properties with regard to deep drawing, all influences other than the sheet properties must be kept constant. In order to determine the extent to which this is feasible an investigation has been started as to the influence of the dimensions of the tools and of the testing conditions on the result of the cupforming test. This investigation may be divided into a theoretical and an experimental part.

It should be borne in mind however that a complete description of sheet quality cannot be obtained by the cup-forming test alone.

2. Analytical Investigation

On the basis of investigations made by Chung and Swift‡ it can be calculated what nominal drawing stress must be exercised in the cupwall at the die-mouth, and at the punch, in order to draw the product under the following conditions:—

(a) A cylindrical cup is to be drawn from a flat blank.

(b) The blankholder is in a position vertical to the axis of the punch.

(c) The unfilled clearance is so wide that the wall of the product is always thinner than this clearance.

In drawing the cup the material which originally lies within the die-mouth is subjected at the punch to a stretch-forming strain under biaxial tension and plastic bending under tension. The latter deformation occurs at the punch profile.

The material, which originally lies outside the die-mouth is deformed under conditions of true radial drawing, which at the die-profile is overlapped by bending under tensile stress. Between the two areas of deformation at punch and die there is a ring of material which is neither bent on the punch-profile nor on the die-profile at the beginning of the process. This ring which is virtually not deformed at the beginning of the test, must conduct the force between the two areas of deformation and is under relatively simple tensile stress.

By drawing the flange within the die, the punch-load is determined, this load causing the deformation at the punch. About the drawing stress much is known already, whereas about the behaviour of the material at the punch only very little is known.

* Paper presented at the "Colloque sur la mise en forme des tôles minces et les essais de tôles" organized by the International Deep Drawing Research Group and the Société Française de Métallurgie, Paris, 1960.

† Deputy Director and Head of Physical Department of the Metal Research Institute T.N.O., Delft, Holland.

‡ *Proc. Inst. Mech. Eng.* 1951, **165**, pp. 199-228.

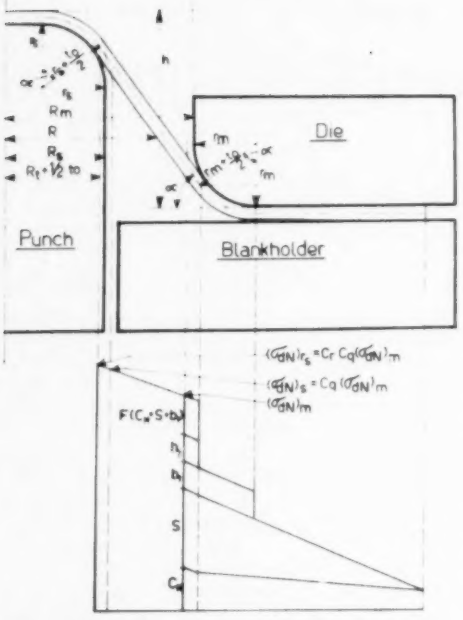


Fig. 1.—Diagram showing composition of drawing stress

2.1. *Drawing Stress**

Fig 1 shows, schematically, how the drawing-stress may be considered to be composed. At the die-mouth the drawing-stress is necessary:—

(a) To effect the drawing-in of the flange: the stress needed is S.

(b) To overcome the friction at the flange: the stress needed is C_H.

(c) To carry out the bending around die-profile: the stress needed is b_1.

(d) To effect the rebending at the die-profile: the stress needed is b_2.

(e) To overcome the friction at the die-profile: the stress needed is $F(C_H + S + b_1)$.

Consequently the nominal drawing stress at the die-mouth, *viz.* $(\sigma_{dN})_m$ can be written:

$$(\sigma_{dN})_m = C_m C_H + C_m S + C_m b_1 + b_2 \quad (1)$$

where $C_m = F + 1$ .. .. .. (2)

The nominal drawing-stress at the punch-diameter $(\sigma_{dN})_s$ or at the largest diameter, where the material touches the punch $(\sigma_{dN})_{rs}$ is proportionally higher, *viz*:

$$(\sigma_{dN})_s = C_q (\sigma_{dN})_m \quad .. \quad .. \quad .. \quad (3)$$

$$(\sigma_{dN})_{rs} = C_R C_q (\sigma_{dN})_m \quad .. \quad .. \quad (4)$$

Concerning the calculation of the stresses from the measurements, reference may be made to Appendix I.

* A list of symbols is given at the end of the paper on page 802.

As is pointed out in Appendix II, $C_m b_1 - b_2$ can be written

$$C_m b_1 + b_2 = C_b^* \bar{Q} \quad .. \quad .. \quad .. \quad (5)$$

where C_b^* has the character of a geometrical quantity and $\bar{Q}$ is a function which is particularly dependent on the yield stress of the sheet at the die-profile. Consequently the nominal drawing stress at the punch-profile can be written:

$$(\sigma_{dN})_{rs} = C_R C_q (C_m C_H + C_m S + C_b^* \bar{Q}) \quad (6)$$

C_q, C_R and C_b describe the tools.

C_R is implicitly present in C_R, *cf.* formula (30).

C_b is implicitly present in C_b^*, *cf.* formula (45).

C_m and C_H describe the testing condition.

C_R is a measure for the tapering of the cup.

S and $\bar{Q}$ are determined by the sheet-properties.

S represents the stress needed to draw-in the flange.

$\bar{Q}$ is a stress function which describes the bending and unbending at the die-profile.

When the C-parameters

C_R C_q C_b^* C_m and C_H

are kept constant for all the sheet thickness and punch diameters, this means that the nominal drawing stress becomes independent of the punch-diameter and the sheet-thickness and is only dependent on the sheet-properties through the function S and $\bar{Q}$.

The requirement that the C-parameters must be constant implies that the tools and testing-conditions must ultimately satisfy the nine following requirements:—

1. According to formula (28) of Appendix I the die-diameter must be a linear function of the punch diameter and of the sheet-thickness according to

$$D_m = C_q D_s + (C_q + 1)\, t_o \quad .. \quad .. \quad (7)$$

where C_q is practically constant and $C_q > 1$.

and D_m = diameter of die

D_s = punch diameter

t_o = sheet thickness

C_q = clearance parameter.

2. According to formula (41) of Appendix II and according to the first approximation of C_b^* = constant by C_b = constant, as pointed out in Appendix II, the die-profile radius must be proportional to the sheet-thickness according to

$$r_m = C_r t_o \quad .. \quad .. \quad .. \quad .. \quad (8)$$

where C_r is practically constant and $C_r > 0$

and r_m = die-profile radius.

$$C_r = \frac{4}{7}\left(\frac{2}{C_b} - 1\right) .. \quad .. \quad .. \quad (9)$$

C_b = die-profile parameter.

3. According to formula (31) of Appendix I and according to the requirement that C_R is constant, the punch-profile radius must be a linear function of the punch diameter and the sheet-thickness according to:—

$$r_s = \frac{1}{2C_R} D_s - \frac{1}{2}\left(1 - \frac{1}{C_R}\right) t_o \quad .. \quad .. \quad (10)$$

where C_s = practically constant and $C_s \geq 1$
and r_s = punch-profile radius
C_s = punch-profile parameter

$C_s = 1$ means $r_s = \frac{1}{2}D_s$, i.e. round-headed punch

$C_s > 1$ means a flat-headed punch.

4. The clearance must be so large that the sheet-material can always move freely between punch and die, *i.e.*, the filled clearance must be more than 40 per cent over and above the sheet-thickness, consequently

$$q = \frac{D_m - D_s - 2t_o}{2t_o} = \frac{C_q - 1}{2}\left(\frac{D_s}{t_o} + 1\right) > 0.40 \quad .. \quad .. \quad .. \quad .. \quad (11)$$

or

$$C_q > 1 + \frac{0.80}{\frac{D_s}{t_o} + 1} \quad .. \quad .. \quad .. \quad (12)$$

5. The blank must be between die and blankholder at the very beginning of the test; this means:

$D_K > D_m + 2r_m$

or

$$C_r < \frac{1}{2}(T_{Ks} - C_q)\left(\frac{D_s}{t_o} + 1\right) - \frac{1}{2} \quad .. \quad (13)$$

where

D_K = limiting blank diameter

$T_{Ks} = \frac{D_K}{D_s + t_o}$ = cuphead — L.D.R.

6. According to formula (36) of Appendix II and the requirement that the flange friction parameter C_H must be constant, the blankholder load must be so chosen that it is a pseudo-volume-force according to

$$H = \pi (D_m - t_o)\, t_o H_o \quad .. \quad .. \quad (14)$$

where H_o = constant
and H = blankholder load
H_o = specific blankholder load related to the section at the die-mouth.

7. The coefficients of friction at the flange must be as constant as possible, in order to keep

$$C_H = (\mu_1 + \mu_2)\, H_o \quad .. \quad .. \quad .. \quad (15)$$

constant with all tests,
where μ_1 and μ_2 = coefficients of friction occurring at both sides of the flange
C_H = flange-friction parameter.

8. The coefficient of friction at the die-profile must be as constant as possible, in order to keep

$$C_m = F + 1 \quad .. \quad .. \quad .. \quad .. \quad (2)$$

constant with all tests,
where F = a function of μ_m and α
μ_m = coefficient of friction at the die-profile
α = angle between the cup wall and the plane of the blankholder.

The friction function $F(\mu_m, \alpha)$ can be approximated by the coil-friction-formula, so that

$$F(\mu_m, \alpha) \approx e^{\mu_m \alpha} - 1 \approx \mu_m \alpha \quad .. \quad .. \quad (16)$$

For a better approximation, reference should be made to Chung and Swift.

9. The depth of the cup at the onset of the fracture must be such that the angle between the cup wall and the plane of the blankholder is greater than $0.9\frac{\pi}{2} = 81$ deg., *i.e.*, $\sin \alpha > 0.99$.

In that case C_R equals unity within less than 1 per cent where

$$C_R = \frac{1}{1 - \frac{1}{C_s}(1 - \sin \alpha)} \quad .. \quad .. \quad (17)$$

and C_R = cup-tapering parameter.

As pointed out in Appendix III, for obtaining $\sin \alpha > 0{,}99$: for usual testing tools:
(a) the depth of the cup must be

$$h \geq 2\,(r_m + r_s + t_o) \quad .. \quad .. \quad .. \quad (18)$$

where
h = depth of the cup.
(b) for $h = 2\,(r_m + r_s + t_o)$ the clearance parameter C_q must satisfy

$$1 < C_q < 1 + 0.1526\left(\frac{1}{C_s} + \frac{1 + 2C_r}{D_s/t_o + 1}\right) \quad (19)$$

In connexion with formula (12) C_q has to be in the interval.

$$1 + \frac{0.80}{\frac{D_s}{t_o} + 1} < C_q < 1 + 0.1526\left(\frac{1}{C_s} + \frac{1 + 2C_r}{\frac{D_s}{t_o} + 1}\right) \quad .. \quad .. \quad .. \quad (20)$$

The requirements 1, 2, 3, 4 + 9(b) and 5 are tool-requirements, whereas the requirements 6, 7, 8 and 9(a) are testing-conditions requirements.

If the conditions that the parameters C_m, C_H and C_s^* must be constant are satisfied with sub-critical blank diameters (blank diameter $< D_K$), the maximum drawing stress at the die-mouth is, in principle, a measure for the drawing stress properties of the sheet, because all tool and testing influences result in the same contribution to the stress in the cup wall at the die-mouth.

The same is true for the maximum nominal drawing stress at the punch-diameter if C_q is constant too, and for the maximum nominal drawing stress at the largest diameter, where the material touches the punch if C_R is also constant. The maximum nominal drawing stress at the die-mouth, punch diameter or punch profile is, in a good approximation, constant for all thicknesses and tool diameters, if C_R, C_q, C_s^*, C_m and C_H are each constant and, furthermore, if the stress deformation characteristics of the material tested are identical, so that S and Q are constant too.

As regards some requirements which so far have been normal, the following may be noted in this connexion:

(a) One of the requirements of the Swift cupping test, which is often mentioned in the literature, is that the tool dimensions would have been proportional to the sheet thickness, *i.e.*, that

$$\frac{D_m}{t_o} = \text{const.} \quad \frac{D_s}{t_o} = \text{const.}$$

$$\frac{r_m}{t_o} = \text{const. and } \frac{r_s}{t_o} = \text{const.}$$

If this requirement has been met, then also:—

$$C_q = \frac{D_m/t_o - 1}{D_s/t_o + 1} = \text{const.}$$

$$C_r = r_m/t_o = \text{const.}$$

$$C_s = \frac{D_s/t_o + 1}{2r_s/t_o + 1} = \text{const.}$$

However, these four requirements are too limited, because

1. The other requirements derived above have not been made.
2. The requirements as to C-parameters furthermore establish a relationship between D_m/t_o D_s/t_o and r_s/t_o, and if $C_b^* = \text{constant}$ is applied instead of $C_b = \text{constant}$, also between r_m/t_o.

Furthermore, it is technically not possible to make the sheet proportionally thinner with a view to testing, without changing the properties.

(b) A requirement which has so far often been made is that filled clearance

$$q = \frac{D_m - D_s - 2t_o}{2t_o}$$

must be constant, independently of the punch diameter and the sheet thickness. From the requirement derived above that the clearance parameter C_q must be constant, it follows on the other hand according to formula (11) that the filled clearance must vary proportionally with $(D_s/t_o + 1)$ *i.e.*,
must increase linearly with the punch diameter and in inverse proportion to the sheet thickness.

(c) Another requirement which has often been made is that the blankholder pressure

$$p_H = \frac{4H}{\pi [D^2 - (D_m + 2r_m)^2]}$$

must be constant, where
D = blank diameter.

Between the above-defined specific blankholder load related to the section at the die-boring H_o and the blankholder pressure p_H, the following relationship exists:—

$$H_o = \frac{1}{4C_q}[(T_s^2 - C_q^2)\ (D_s/t_o + 1) - 2C_q\ (2C_r + 1) - \frac{(2\ C_r + 1)^2}{D_s/t_o + 1}]p_H \quad \ldots.(21)$$

where

$$T_s = \frac{D}{D_s + t_o}$$

is the cup-head drawing ratio.

The ratio between H_o and p_H is a function of the cup-head drawing ratio T_s, the ratio D_s/t_o, the clearance parameter C_q and the die-profile ratio C_r.

At constant p_H, H_o increases with increasing D_s/t_o and increasing blank diameter.

(d) Another requirement which is often made with regard to the flange load is that the blankholder load H must be constant.

Because between H and H_o the following relation exists

$$H_o = \frac{H}{\pi\ (D_m - t_o)\ t_o} = \frac{H}{\pi\ Cq\ (D_s + t_o)\ t_o}$$

this means that for H = constant and C_q = constant, H_o decreases with increasing D_s and or increasing t_o.

On the basis of c. and d. the fact, which was mentioned in the introduction, can be explained that when punches of increasing diameters are used the LDR decreases, if the blankholder pressure p_H is kept constant, whereas the LDR increases, if the blankholder load H is kept constant. Because if at constant blankholder pressure p_H and at constant drawing ratio T_s the cupforming test is performed with punches of increasing diameters, then the specific blankholder load H_o increases, in accordance with formula (21). Consequently the flange friction parameter C_H also increases. If C_R, C_q, C_m, C_b^* and Q do not vary with the punch diameter, a certain value of the drawing stress is reached at a lower drawing-in stress S if the punch diameter D_s is increased. This means, therefore, that the LDR also decreases with increasing punch diameter.

If the blankholder load is kept constant, the specific blankholder load H_o decreases with increasing punch diameter, and hence the LDR increases.

2.2. *Behaviour of the Material at the Punch-Profile*

It is only possible to draw a product if the maximum punch load required to draw-in the flange, does not cause the limit to be exceeded at which fracturing occurs at the punch (the so-called breaking strength). The question whether the metal is able to transmit the load for drawing-in the flange therefore much depends on the behaviour of the material at the punch-profile. Normally fracturing occurs at the punch-profile where the material which previously has not been work hardened, has become thinner, due to bending under tensile stress. This place of failure may lie on the punch profile, but also in the cupwall at a little distance from the punch-profile. The latter situation occurs when the die-profile radius is small in relation to the sheet thickness.

A small punch-profile radius causes severe local thinning without the bottom being stretched much. A large profile radius yields a more equal thinning of the entire curvature, the diameter of the fracture circle becoming smaller with decreasing friction.

The punch load is used to stretch the metal in the bottom at the punch, to bend it across the profile and, if it can move across the profile, to stretch it and rebend it and finally to overcome the friction during movement across the profile.

The entire process is highly involved and at the moment the distribution of stresses and where exactly fracturing may be expected, are not known. It is therefore of paramount importance to obtain more information on the behaviour of the metal at the punch and in its direct environment.

2.3. *Limiting Drawing Ratio*

Fracturing will occur, when the drawing-stress becomes equal to the breaking strength, *i.e.*, starting from a critical blank diameter D_K which depends on tools and testing conditions. The limiting blank diameter D_K is the blank diameter at which an agreed percentage of the products fails, for example 50 per cent or 20 per cent.

The limiting drawing ratios of various types of sheet show little mutual variations. It is therefore essential that high requirements are to be made as regards the testing method and testing equipment, and also that the magnitude to be measured is likewise determined as accurately as possible. Therefore in the LDR and LFDR the sheet thicknesss cannot be neglected and as a magnitude to be measured the cuphead-LDR, respectively the cupfoot-LFDR (the cupfoot limiting flange drawing ratio) must be chosen instead of the conventional LDR.

The cuphead-LDR is defined as the ratio of the limiting blank diameter D_K to the sum of the punch diameter D_s and the sheet thickness t_o, *i.e.*,

$$T_{ks} = \frac{D_k}{D_s + t_o} \quad .. \quad .. \quad .. \quad .. \quad (22)$$

whereas the conventional LDR is defined as

$$T_k = \frac{D_k}{D_s} \quad .. \quad .. \quad .. \quad .. \quad (23)$$

The cupfoot-LDR is defined as

$$T_{km} = \frac{D_k}{D_m - t_o} = \frac{1}{C_q} T_{ks} \quad .. \quad (24)$$

Furthermore, the limiting flange to be drawn-in is

$$D_{kF} = D_k - (D_m - t_o) \quad .. \quad .. \quad (25)$$

The cupfoot-LFDR may be defined as

$$T_{kFm} = \frac{D_{kF}}{D_m - t_o} = T_{km} - 1 = \frac{1}{C_q}(T_{ks} - 1) \quad .. \quad .. \quad .. \quad (26)$$

Actually for the cuphead-LDR, the cupfoot-LDR and the cupfoot-LFDR the true sheet thickness t_o, respectively t_m, should be substituted. Because in a good approximation at the maximum punch load $t_o = 0.9\, t_o$ and $t_m = 1.1\, t_o$ this means that

$$T_{ks_{max}} = \left(1 + \frac{0.1}{D_s / t_o + 1}\right) T_{ks}$$

$$T_{kFm_{max}} = \left(1 + \frac{0.1}{C_q (D_s / t_o + 1)}\right) T_{kFm}$$

The difference is largest for the lowest value of D_s / t_o, which is for the usual tools about 25. In this case, $T_{ks_{max}} = 1.004\ T_{ks}$ and $T_{kFm_{max}} = 1.004\ T_{kFm}$, so that the difference may be neglected.

The relation between the cuphead-LDR and the conventional-LDR is

$$T_k = (1 + t_o / D_s)\, T_{ks}.$$

The difference between T_k and T_{ks} decreases with increasing ratio D_s / t_o. For usual testing tools with

$$74 > D_s / t_o > 25$$

this means that the conventional LDR lies in the interval

$$1.01\, T_{ks} < T_k < 1.04 T_{ks}.$$

Whereas the difference is rather considerable, it is recommended for testing purposes not to determine the conventional LDR, but the more accurate cuphead LDR, respectively cupfoot-LFDR, as mentioned above. The cupfoot-LFDR may be of importance if an impression should be obtained of the flange drawn-in, which is useful in investigations of the drawing-in stress S, and as to the influence of the clearance parameter C_q. Because in all cases when the clearance parameter C_q is constant, the cup-head LDR is, as a quantity of measurement as the cupfoot-LFDR, as follows from formula (26). Only when also the clearance parameter varies, the cupfoot-LFDR is preferable to the cuphead LDR, in order to get proper insight. Together with the drawing stress at the die-boring, the cupfoot-LFDR then gives an impression on the drawing-in properties of the sheet. Whereas the cuphead-LDR together with the breaking-strength at the punch can yield an impression as to the deep-drawing properties of the material.

3. Experimental Investigation

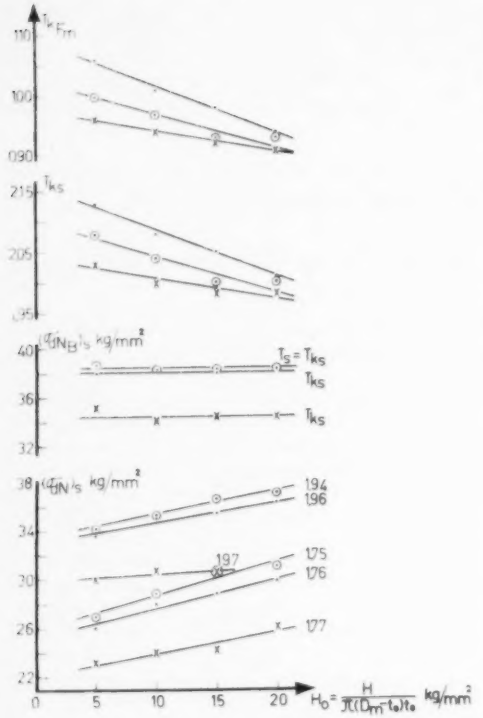
In order to test the formulae for the drawing stress (1 and 6), the cuphead-LDR (22) and the cupfoot-LFDR (26) tools have been made which satisfy the requirements made, and the experiments have been performed under the conditions required. It should be mentioned that for the true die-profile parameter a simplified requirement has been applied, *viz.* the die-profile parameter C_b (8 and 9).

The measurements are subdivided into four groups, *viz.*:

(a) Measurement of the maximum drawing stress at blank diameters, which are *smaller* than the limiting blank diameter, in order to investigate the effect of the C-parameters on the drawing stress.

(b) Measurement of the maximum drawing stress at the *limiting* blank diameter in order to investigate the effect of the C-parameters on the nominal breaking strength.

(c) Measuremen. of the cuphead-LDR in order to determine the influence of the C-parameters on this LDR. The cuphead-LDR is the LDR at which 50 per cent of the products failed.



		Sheet	t_o	D_s	Cq	Ho	C_r	C_s	q
			mm	mm		kg/mm²			
•	I	Steel SEDD	1.03	50.0	1.036	—	6.60	5.06	0.89
×	II	Brass 63/37	0.81	50.0	1.035	—	7.41	4.95	1.09
⊙	III	Steel EDD	0.76	25.0	1.037	—	7.11	5.07	0.62

Fig. 2.—Influence of specific blankholder hood

(d) Measurement of the cupfoot-LFDR in order to determine the value of this magnitude for studying deep-drawing.

In appendix 4 the corresponding results of measurements are given, which are illustrated by Figs. 2 up to and including 6 and Tables IX, X and XI.

3.1. *Influence of the Specific Blankholder Load*

Fig. 2 shows the influence of the specific blankholder load (related to the section at the die-boring) H_o (14). At constant coefficient μ_1 and μ_2 of flange friction, the flange friction parameter C_H is proportional to H_o. In agreement with the expectations of the analytical investigation it is found that:

(a) The nominal drawing stress at the punch (6) at sub-critical blank diameters, increases linearly with the specific blankholder load.

(b) The nominal breaking strength at the punch is independent of the specific blankholder load.

(c) The cuphead-LDR and the cupfoot-LFDR decrease linearly with increasing specific blankholder load H_o. This can be explained from the fact that the breaking strength remains constant. Thus an increase of the specific blankholder load H_o, *i.e.*, of the flange friction parameter C_H in formula (6) must be compensated by a decrease of the drawing-in stress S, which means that a smaller flange D_{KF} can be drawn-in, or that the cupfoot-LFDR decreases and because of constancy of C_r, that the cuphead LDR decreases too.

3.2. *Influence of the Die-profile Parameter, C_b*

Fig. 3 shows the influence of the die-profile parameter C_b.

(a) The nominal drawing-stress at the punch at subcritical blank diameters increases, as was expected according to formulae (6) and (45), linearly with C_b, but only if C_b is larger than about

TABLE I—*Influence of the specific blankholder-load Ho* $= \frac{H}{\pi (D_m - t_o) t_o}$

	H_o kg/mm²	H kg	D_k mm	P_{max} kg	h_{max} mm	C_b	$(\sigma_d NB)_s$ kg/mm²	T_{ks} kg/mm²	T_{KFm}
I	5.0	845	108.8	6,259	28.07	2.27	38.0	2.13	1.06
	10.0	1,710	106.4	6,325	26.06	2.11	38.3	2.08	1.01
	15.0	2,555	104.5	6,265	24.22	1.96	38.0	2.05	0.98
	20.0	3,420	102.5	6,316	23.25	1.88	38.3	2.01	0.94
II	5.0	670	103.2	4,539	29.16	2.53	35.1	2.03	0.96
	10.0	1,340	101.8	4,386	28.92	2.51	33.9	2.00	0.94
	15.0	2,010	100.8	4,417	28.83	2.50	34.2	1.98	0.92
	20.0	2,680	100.5	4,463	27.92	2.42	34.5	1.98	0.91
III	5.0	320	53.5	2,380	13.72	1.65	38.7	2.08	1.00
	10.0	640	52.5	2,355	13.45	1.62	38.3	2.04	0.97
	15.0	960	51.6	2,355	13.80	1.66	38.3	2.00	0.93
	20.0	1,280	51.5	2,355	12.87	1.55	38.3	2.00	0.93

TABLE II—*Influence of the specific blankholder load* $H_s = \frac{H}{\pi (D_m - t_0) r_0}$

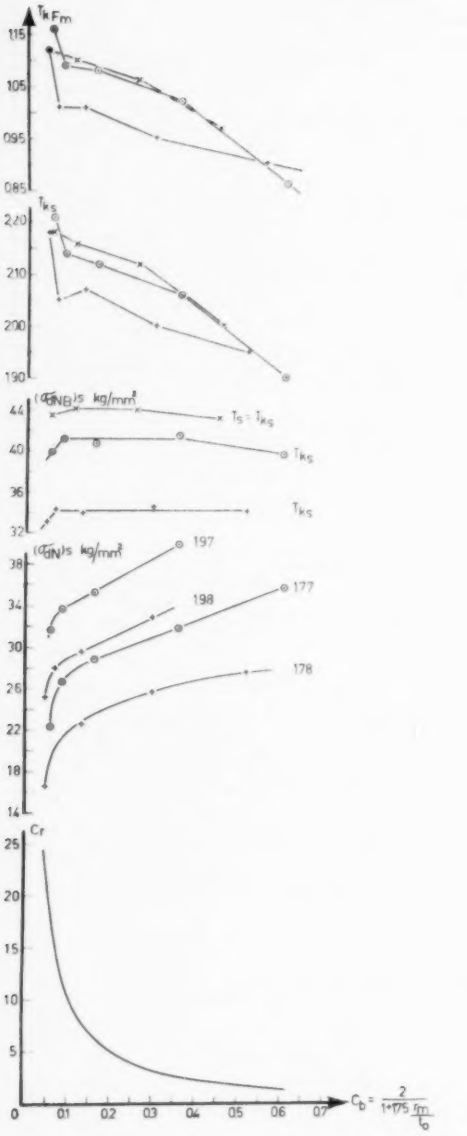
	H_s kg/mm²	H kg	D = 90 mm T_s	P_{max} kg	h_{max} mm	C_h	$(\sigma_d N)_s$ kg/mm²	D = 100 mm T_s	P_{max} kg	h_{max} mm	C_h	$(\sigma_d N)_s$ kg/mm²
I	5.0	845	1.76	4,290	18.22	1.47	26.0	1.96	5,536	22.20	1.80	33.6
	10.0	1,710		4,616	18.46	1.49	28.0		5,778	22.94	1.86	35.0
	15.0	2,555		4,756	19.34	1.56	28.8		5,818	24.12	1.95	35.3
	20.0	3,420		4,918	19.32	1.56	29.8		5,960	24.76	2.00	36.2
II	5.0	670	1.77	2,990	21.60	1.87	23.1	1.97	3,863	27.20	2.36	29.9
	10.0	1,340		3,085	22.64	1.96	23.8		3,965	28.44	2.46	30.6
	15.0	2,010		3,113	22.30	1.93	24.1		3,935	28.86	2.50	30.4
	20.0	2,680		3,354	22.42	1.94	26.0			all failed		
			D = 45 mm					D = 50 mm				
III	5.0	320	1.75	1,620	9.68	1.16	27.0	1.94	2,100	12.10	1.45	34.2
	10.0	640		1.730	9.56	1.15	28.9		2,170	12.40	1.49	35.3
	15.0	960		1,820	9.50	1.14	30.5		2,250	12.48	1.50	36.6
	20.0	1,280		1,870	9.70	1.17	31.1		2,280	12.80	1.54	37.1

TABLE III—*Influence of the die-profile parameter* C_h

	r_m mm	C_r	C_h	D = 90 mm T_s	P_{max} kg.	h_{max} mm	C_h	$(\sigma_d N)_s$ kg/mm²	D = 100 mm T_s	P_{max} kg.	h_{max} mm	C_h	$(\sigma_d N)_s$ kg/mm²
IV	1.0	1.32	0.604	1.77	4,334	18.44	2.84	35.8	1.97		all failed		
	2.0	2.63	0.357		3,861	16.96	2.26	31.9		4,836	24.16	3.23	39.9
	5.0	6.58	0.160		3,503	17.26	1.65	28.9		4,272	20.58	1.96	35.3
	10.0	13.26	0.083		3,239	18.92	1.22	26.7		4,084	23.22	1.50	33.7
	15.0	19.74	0.056		2,600	20.26	0.99	22.3		4,835	24.02	1.17	31.7
VI	1.0	1.64	0.517	1.78	2,675	24.08	3.08	27.6	1.98		all failed		
	2.0	3.28	0.297		2,505	23.42	3.19	25.8		3,188	31.30	4.26	32.9
	5.0	8.20	0.130		2,189	21.56	2.09	22.6		2,873	27.62	2.67	29.6
	10.0	16.39	0.067		2,041	22.24	1.45	21.1		2,710	29.26	1.91	28.0
	15.0	24.59	0.045		1,611	24.76	1.22	16.6		2,430	27.30	1.34	25.1

TABLE IV—*Influence of the die-profile parameter* C_h

	r_m mm	C_r	C_h	D_k mm	P_{max} kg.	h_{max} mm	C_h	T_{ks}	T_{KFm}	$(\sigma_d NB)_s$ kg/mm²
IV	1.0	1.32	0.604	96.5	4,799	23.90	3.68	1.90	0.86	39.6
	2.0	2.63	0.357	104.8	5,031	26.37	3.52	2.06	1.02	41.5
	5.0	6.58	0.160	107.8	4,927	23.53	2.24	2.12	1.08	40.7
	10.0	13.26	0.083	108.6	4,992	26.59	1.72	2.14	1.09	41.2
	15.0	19.74	0.056	112.2	4,828	31.92	1.56	2.21	1.16	39.9
V	1.0	1.96	0.452	102.3	3,457	25.75	3.4	2.03	0.96	43.1
	2.0	3.92	0.255	107.5	3,518	23.3	2.7	2.13	1.06	43.9
	5.0	9.80	0.110	109.2	3,523	26.4	2.3	2.16	1.10	44.0
	10.0	19.60	0.057	110.5	3,475	28.55	1.75	2.19	1.12	43.4
VI	1.0	1.64	0.517	98.5	3,310	29.20	4.61	1.95	0.90	34.1
	2.0	3.28	0.297	101.2	3.340	38.56	3.89	2.00	0.95	34.5
	5.0	8.20	0.130	104.8	3,290	30.06	2.91	2.07	1.01	33.9
	10.0	16.39	0.067	103.5	3,320	31.20	2.03	2.05	1.01	34.3
	15.0	24.59	0.045	110.5	3.210	36.06	1.77	2.18	1.12	33.1



		Sheet	t_o	D_s	C_q	H_o	C_r	C_s	q
			mm	mm		kg/mm²			
⊙	IV	Steel EDD	0.76	50.0	1022	10.0	—	4.97	0.73
×	V	Steel	0.505	50.0	1032	10.0	—	3.97	1.60
+	VI	Brass 63/37	0.61	50.0	1028	10.0	—	5.03	1.16

Fig. 3.—Influence of die-profile parameter C_b

0.1, *i.e.*, when the profile radius of the die is smaller than a given value (about 10 times the sheet thickness).

The sharp decrease of the stress at smaller values of C_b is caused by the fact that the flange is entirely on the big die-profile so that there is no blankholder load on the flange and, therefore, the flange friction parameter C_H equals zero before the maximum load is reached.

(b) The nominal breaking strength at the punch as a function of C_b may be divided in three ranges. In the interval of about 0.1 to about 0.3 the breaking strength is practically constant. To the left and to the right of this range, *i.e.*, for large and small die-profile radii, the breaking strength is smaller.

The decrease of the breaking strength with small die-profile radii is due to the fact that in the beginning of the experiments the thinning of the sheet due to bending is greater the smaller the die-profile radius. The failure now occurs at this greatly thinned area instead of at the die-profile.

Why the breaking strength for larger die-profile radii becomes lower is not entirely clear. The decrease may be due to the fact that the angle between the cup wall and the plane of the blankholder becomes smaller, the bigger the die-profile radius is; *i.e.*, the maximum diameter, where the material touches the punch profile is smaller, causing more thinning because of less friction.

(c) The cuphead-LDR and the cupfoot-LFDR as a function of C_b can likewise be divided in three ranges.

In the interval from about 0.1 to about 0.3 the slope of the curve is smaller than to the left or to the right of it. In this centre-range the LDR or LFDR becomes smaller with increasing C_b, because at constant breaking strength the increase of C_b must be compensated by a decrease of the drawing stress S.

To the right of this range, *i.e.*, for smaller die-profile radii, the breaking strength decreases too, so that the decrease of S must be more pronounced now. To the left of the centre range the slope of the curve is greater because at decreasing C_b, as from a given profile radius, the friction of the flange, *i.e.*, the term $C_m C_H$ in formula (6) disappears.

3.3. *Influence of the Punch-profile Parameter, C_s*

Fig. 4 shows the influence of the punch-profile-parameter C_s, which is implicitly present is C_R according to formula (17).

(a) The nominal drawing stress at the punch at subcritical blank diameters is, as was to be expected, independent of C_s. Actually the punch profile parameter C_s is not included in the stress-formula (6), if the shape of the cup is a cylindrical one ($\sin \alpha > 0.99$).

(b) The nominal breaking strength at the punch distinctly and uniformly decreases with increasing C_s.

This decrease starts at $C_s = 1$, *i.e.*, at a round-headed punch and is due to the fact that the thinning consequent to bending around the punch profile increases with the punch profile becoming sharper.

(c) The cuphead-LDR and the cupfoot-LFDR decreases with increasing punch profile parameter, because the breaking strength decreases.

3.4. *Influence of the Clearance Parameter, C_q*

In this investigation it is not easy to vary the clearance parameter C_q only.

Because if the blank diameter D is kept constant then, together with C_q, the width of flange D_r varies, if the variation of C_q occurs due to a variation of the die-boring. If the variation of C_q is caused by a decrease in diameter of the punch, then the reference diameter D_r changes, so that the cuphead-LDR becomes proportionally bigger at constant flange width.

The tests performed with constant punch diameter and variation of the die-diameter, are mentioned in Figs. 5 and 6.

(a) The nominal drawing stress at the punch profile at constant subcritical blank diameters decreases with increasing clearance parameter C_q. This rather considerable decrease is due to the fact that at increasing C_q the flange to be drawn-in becomes smaller, *i.e.*, the drawing-stress S decreases in formula (6). Furthermore the true die-profile parameter C_o^* (45) slightly decreases. However, this decrease has little influence.

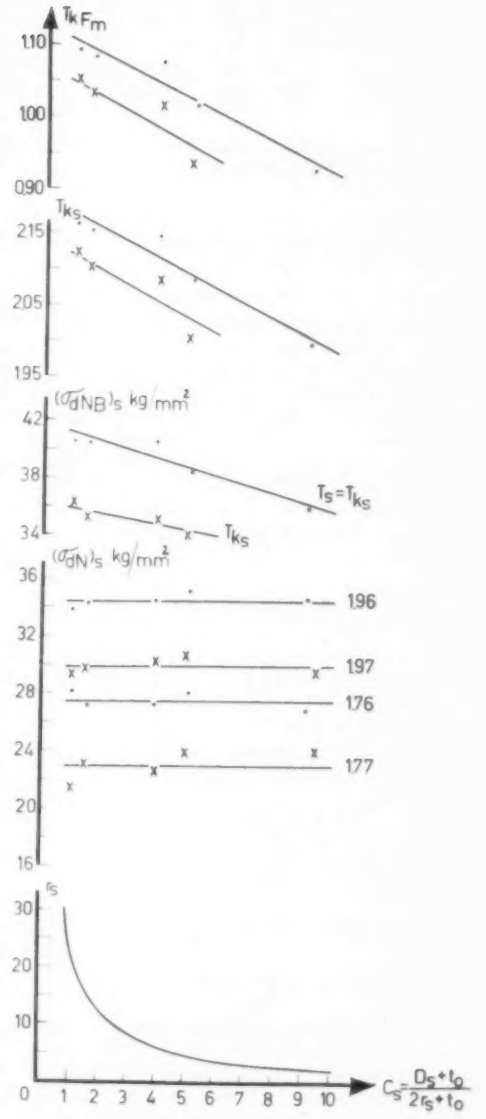
Thus at constant blank diameter the downward slope of the curve is mainly determined by the fact that the influence of the drawing-in stress S on the nominal drawing stress is much larger than the influence of the clearance parameter C_q.

(b) The breaking strength at the punch profile very slightly decreases with increasing C_q, *viz.* about 0.4 per cent with a variation of 0.01 in C_q. This decrease may be caused by the fact that the angle between cupwall and plane of the blankholder becomes the smaller, the more C_q increases, causing more thinning at the punch-profile.

If wall-ironing is applied, the breaking strength considerably increases as appears for $C_q = 0.99$.

(c) The cuphead-LDR increases rather considerably with C_q. This is due to the fact that at increasing C_q at the beginning of the test a proportionally bigger ring of material lies between the punch and the die-boring and only the remaining ring between the blankholder and die contributes to the nominal drawing stress. If wall-ironing is applied the cuphead-LDR increases, because the breaking strength is larger.

(d) The cupfoot-LFDR decreases with C_q. This is due to the fact that at increasing C_q the drawing stress at the punch increases proportionally to C_q. Because the breaking strength being nearly



		Sheet	t_o mm	D_s mm	C_q	H_o kg/mm²	C_r	C_s	q
•	XII	Steel SE00	1.03	50.0	1.036	10.0	6.60	—	0.89
×	XII	Brass 63/37	0.81	50.0	1.035	10.0	7.41	—	1.09

Fig. 4.—Influence of punch-profile parameter C_s

TABLE V—*Influence of the punch-profile parameter C_r*

	r_s mm	C_r	D = 90 mm					D = 100 mm				
			T_s	P_{max} kg	h_{max} mm	C_h	$(\sigma dN)_h$ kg/mm^2	T_s	P_{max} kg	h_{max} mm	C_h	$(\sigma dN)_h$ kg/mm^2
VII	2.30	9.06	1.76	4,420	18.14	1.79	26.8	1.96	5,678	22.46	2.22	34.4
	4.53	5.06		4,616	18.46	1.49	28.0		5,778	22.94	1.86	35.0
	6.10	3.86		4,498	19.80	1.42	27.2		5,686	23.34	1.68	34.4
	16.70	1.53		4,336	25.88	1.06	27.1		5,638	29.72	1.21	34.2
	25.00	1.00		4,180	30.66	0.93	28.1		5,576	35.92	1.09	33.8
VIII	2.30	9.39	1.77	3,084	21.76	2.39	23.9	1.97	3,798	27.50	3.02	29.4
	4.53	4.95		3,085	22.64	1.96	23.8		3,965	28.44	2.46	30.6
	7.10	3.91		2,917	22.44	1.74	22.6		3,902	28.30	2.19	30.3
	16.70	1.49		2,966	27.94	1.19	23.0		3,836	33.44	1.42	29.7
	25.00	1.00		2,700	32.32	1.02	21.4		3,780	38.40	1.21	29.3

TABLE VI—*Influence of the punch-profile parameter C_s*

	r_s mm	C_s	D_s mm	P_{max} kg	h_{max} mm	C_h	T_{Fs}	T_{KFm}	$(\sigma_d NB)_s$ kg/mm^2
VII	2.30	9.06	101.5	5,895	19.81	1.96	1.99	0.92	35.7
	4.53	5.06	106.4	6,325	26.06	2.11	2.08	1.01	38.3
	6.10	3.86	109.4	6,671	28.41	2.04	2.14	1.07	40.4
	16.70	1.53	109.6	6,658	35.91	1.46	2.15	1.08	40.4
	25.00	1.00	110.4	6,685	40.23	1.23	2.16	1.09	40.5
VIII	4.53	4.59	101.8	4,386	28.92	2.51	2.00	0.93	33.9
	6.10	3.91	105.8	4,522	29.56	2.29	2.08	1.01	35.0
	16.70	1.49	106.8	4,543	37.97	1.62	2.10	1.03	35.2
	25.00	1.00	107.8	4,686	42.95	1.35	2.12	1.05	36.3

constant, this increase is compensated by a decrease of the flange drawing ratio related to the die-boring.

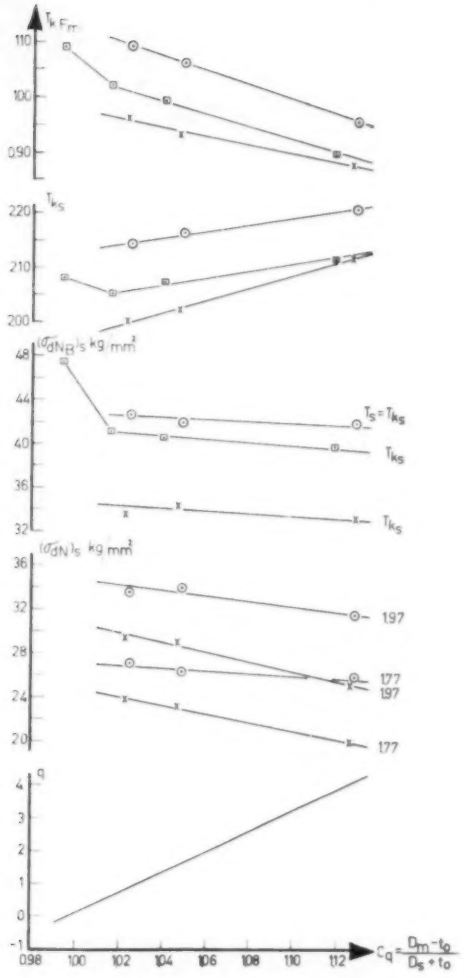
(e) For better understanding of the process Fig. 6 gives a plot of the nominal drawing stress at the die-boring (1) *vs.* the cupfoot-FDR at two subcritical blank diameters and at the limiting blank diameter.

With one blank diameter the nominal drawing stress at the die-boring increases, as was expected from formula (1), with the flange ratio, because the drawing-in stress increases. It seems that flanges with the same outer diameter give linearity between the nominal drawing stress at the die-boring and the cupfoot-FDR. A plot of the nominal drawing stress at the punch *vs.* the cupfoot-FDR gives a linear connexion with a positive slope at each blank diameter.

The same is true for the breaking strength at the punch. The cause of the latter effect is pointed out in(b).

TABLE VII—*Influence of the clearance parameter C_H*

	D_m mm	C_H	q	H kg	D = 90 mm							D = 100 mm							
					T_s	T_{Fm}	Pmax kg	hmax mm	C_H	sinz	$(\sigma dN)_h$ kg/mm^2	$(\sigma dN)_{Hm}$ kg/mm^2	T_s	T_{Fm}	P max kg	h max mm	C_h	sinz	C_H	$(\sigma dN)_h$ kg/mm^2	$(\sigma dN)_{Hm}$ kg/mm^2
IX	52.8	1.025	0.84	1,230	1.77	0.74	3,269	16.02	1.51	1	27.0	26.3	1.97	0.93	4,046	20.18	1.91	1	1.000	33.4	32.6
	54.0	1.049	1.63	1,270		0.70	3,170	18.36	1.73	1	26.2	25.0		0.89	4,098	20.62	1.95	1	1.000	33.8	32.2
	58.0	1.128	4.26	1,370		0.58	2,955	18.86	1.78	0.95	25.7	22.8		0.76	3,704	23.38	2.21	0.98	1.004	31.3	27.7
XI	52.8	1.023	0.73	1,320	1.77	0.73	3,061	21.70	2.04	1	23.7	23.2	1.97	0.92	3,792	26.68	2.51	1	1.000	29.4	28.7
	54.0	1.047	1.47	1,350		0.69	2,973	21.88	2.06	1	23.0	22.0		0.88	3,734	27.80	2.61	1	1.000	28.9	27.6
	58.0	1.126	3.94	1,450		0.57	2,450	21.10	1.98	0.97	19.7	17.5		0.75	3,180	28.14	2.64	0.79	1.002	24.9	22.1



		Sheet	t_o	D_s	C_q	H_o	C_r	C_s	q
			mm	mm		kg/mm²			
⊙	IX	Steel EDD	0.76	50.0	—	10.0	6.70	4.96	—
⊡	X	Steel EDD	0.98	50.0	—	10.4	5.10	3.87	—
×	XI	Brass 63/37	0.81	50.0	—	10.0	6.30	4.94	—

Fig 5 (above).—Influence of clearance parameter C_q

Fig. 6. (right).—Nominal drawing stress plotted against the cupfoot-FDR at two subcritical blank diameters and at the limiting blank diameter

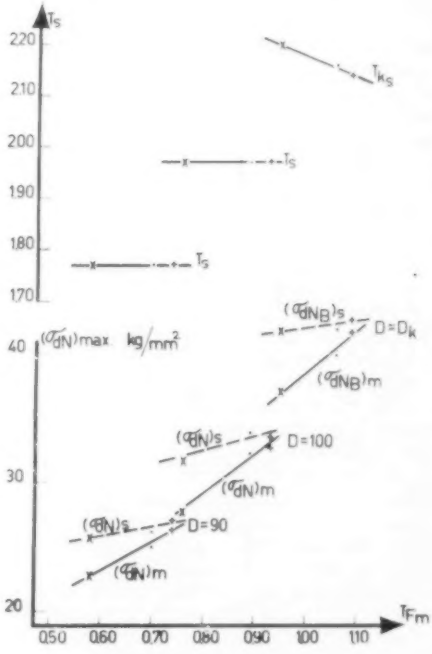
In the case of limiting drawing it is apparent that at constant punch diameter the cuphead-LDR increases with decreasing cupfoot-LFDR, *i.e.*, the blank diameter increases whereas the flange ratio related to the die-boring decreases, and the clearance parameter C_q increases too.

3.5. *Influence of Friction*

Table IX shows the influence of friction by altering the lubricant. From this table it is clear that the breaking strength is not appreciably influenced by the choice of the lubricant. On the other hand the cuphead-LDR and the cupfoot-LFDR are very much affected.

3.6. *Influence of the Punch Diameter*

Tables X and XI give measurements at four punch diameters of tools, which satisfy the requirements made with regard to constant tool influences (constant die-profile parameter C_k, fairly good constant punch-profile parameter C_s and constant clearance parameter C_q) and constant lubricant. In Table II the specific blankholder load related to the section at the die-boring has been kept constant,



		Sheet	t_o	D_s	C_q	H_o	C_r	C_s	q
			mm	mm		kg/mm²			
×	IX	Steel EDD	0.76	50.0	1.128	10.0	6.70	4.96	4.26
•	IX	Steel EDD	0.76	50.0	1.049	10.0	6.70	4.96	1.63
+	IX	Steel EDD	0.76	50.0	1.025	10.0	6.70	4.96	0.84

TABLE VIII—*Influence of the clearance-parameter C_q*

	D_m mm	C_q	q	H kg	D_k mm	P_{max} kg	h_{max} mm	C_h	sinz	C_R	T_{ks}	T_{KF}	$(\sigma_d NB)_s$ kg/mm²	$(\sigma_d NB)_m$ kg/mm²
IX	52.8	1,025	0.84	1,220	108.5	5,147	23.46	2.22	1	1,000	2.14	1.09	42.5	41.5
	54.0	1,049	1.63	1,270	109.4	5,056	24.08	2.27	1	1.000	2.16	1.06	41.8	39.8
	58.0	1,128	4.26	1,370	111.8	4,922	27.76	2.62	0.98	1,004	2.20	0.95	41.6	36.9
X	51.6	0,994	−0.18	1,590	105.8	7,442	39.2	3.4	1	1.000	2.08	1.09	47.4	47.7
	52.8	1,016	0.43	1,630	104.4	6,440	24.7	2.1	1	1.000	2.05	1.02	41.0	40.3
	54.0	1,040	1.04	1,660	105.8	6,325	28.0	2.3	1	1.001	2.07	0.99	40.4	39.0
	58.0	1,118	3.08	1,790	107.6	6,040	27.9	2.3	0.98	1.006	2.11	0.89	39.5	35.3
XI	52.8	1,023	0.73	1,320	101.4	4,334	25.67	2.41	1	1.000	2.00	0.96	33.6	32.7
	54.0	1,047	1.47	1,350	102.5	4,427	27.86	2.62	1	1.000	2.02	0.93	34.3	32.8
	58.0	1,126	3.94	1,450	107.2	4,267	29.82	2.80	1	1,000	2.11	0.87	33.0	29.3

TABLE IX—*Influence of Friction*

Steel DD 1.18 mm

Lubricant	D_s	C_q	H_o	C_r	C_s	q	$(\sigma_d NB)_s$	T_{ks}
Calma Comp. F	33	1.025	10.0	5.08	1.00	0.36	38.8	2.00
Garia 31	33	1.025	10.0	5.08	1.00	0.36	38.3	2.06
H.T.G.	33	1.025	10.0	5.08	1.00	0.36	39.5	2.19

whereas in Table III the flange load itself has been kept constant.

At constant specific blankholder load, the cuphead-LDR is independent of the punch diameter. The standard deviation is only 0.25 per cent.

At constant blankholder load, on the other hand, the cuphead-LDR clearly increases with increasing punch diameter.

4. Conclusions

1. The cup-forming test is complex for, among other things, the tools and testing conditions very much affect the result.

2. It is feasible to choose tools and testing conditions which are determined by the C-parameters of the stress formula, in such a manner that the nominal drawing stress, the breaking strength and the cuphead-LDR or the cupfoot-LFDR become particularly independent of the sheet thickness and the punch-diameter and, consequently only vary with the sheet-properties. For this purpose nine requirements must be satisfied.

3. The disadvantage of the cup-forming test which satisfies the nine requirements, are that many tools, as well as highly accurate apparatus are required and that the test is time-consuming. If such exacting requirements are not satisfied, there is little point in applying the cup-forming test.

4. The determination of the so-called cuphead-LDR or cupfoot-LFDR instead of the conventional-LDR is recommended because these values are more accurate.

5. In all cases when the clearance parameter C_j is constant, the cuphead-LDR is equally as useful as the cupfoot-LFDR.

6. If the clearance parameter C_j also varies, then the cupfoot-LFDR is preferable to the cuphead-LDR, in order to give an accurate result. Then the cupfoot-LFDR cannot be replaced by the cuphead-LDR, because the influence of the clearance parameter on both is opposite.

7. The cuphead-LDR together with the breaking strength at the punch can yield an impression as to the deep-drawing properties of the material.

8. The cupfoot-LFDR together with the drawing stress at the die-bore are useful to gain an impression of the drawing-in properties of the sheet.

TABLE X—*Influence of Punch Diameter*

Steel EDD 0.81mm

D_s	C_q	H_o	C_r	C_s	q	$(\sigma_d NB)_s$	T_{ks}
26	1.019	10.0	4.94	3.94	0.32	39.2	2.03
33	1.019	10.0	4.94	3.84	0.41	40.6	2.03
40	1.019	10.0	4.94	3.78	0.49	39.8	2.04
50	1.019	10.0	4.94	3.97	0.62	40.8	2.04

Specific Blankholder Load H_o = 10.0 kg/mm²

TABLE XI—*Influence of Punch Diameter*

D_s	C_q	H_o	C_r	C_s	q	$(\sigma_d NB)_s$	T_{ks}
26	1.019	10.8	4.94	3.94	0.32	38.7	2.01
33	1.019	8.6	4.94	3.84	0.41	40.5	2.03
40	1.019	7.1	4.94	3.78	0.49	39.6	2.05
50	1.019	5.7	4.94	3.97	0.62	41.5	2.07

Blankholder Load H = 750 kg

9. The cuphead-LDR, with respect to the cupfoot-LFDR, decreases with increasing:

(a) specific blankholder load H_o related to the section at the die-boring.
(b) die-profile parameter C_b (decreasing die-profile radius).
(c) punch-profile parameter C_s (decreasing punch profile radius).

10. The cuphead-LDR increases with increasing clearance parameter C_j (increasing clearance), whereas the cupfoot-LFDR decreases.

11. The cuphead-LDR, with respect to the cupfoot. LFDR is very much affected by the choice of the lubricant.

12. The breaking strength at the punch depends

(a) greatly on the punch profile parameter C_s.
(b) slightly on the die-profile parameter C_b.
(c) slightly on the clearance parameter C_j.
(d) not appreciably on the choice of the lubricant.

13. The breaking strength at the punch is independent of

(a) the specific blankholder load, H_o.
(b) the die-profile parameter C_b in the range from about 0.1 to 0.3.

14. The decrease of the cuphead-LDR with respect to the cupfoot-LFDR with increasing H_o or C_b is caused by increasing the drawing stress at the punch at mainly constant breaking strength.

The decrease of the cuphead-LDR with respect to the cupfoot-LFDR with increasing C_s is caused by decreasing the breaking strength at constant drawing stress.

The decrease of the cupfoot-LFDR with increasing C_j is caused by increasing the drawing stress at nearly constant breaking strength.

15. It is possible to predict with the aid of a laboratory test the outcome of deep drawing a cylindrical cup in practice.

16. It is emphasized that all investigations in this field are still in full swing and have by no means been completed. In addition special attention will be paid to the behaviour of the material at the punchhead, to the breaking strength and to the friction at die- and punch-profile.

APPENDIX I

Because only the maximum stress is of importance, the maximum nominal stress is quoted, unless stated otherwise.

The nominal drawing stresses (1), (3), (6) are magnitudes which can easily be calculated from the measurements. If

P_{max} = maximum punch load.
D_m = diameter of die-bore.
t_o = original sheet thickness.
α = the angle which the cupwall makes with the plane of the blankholder.

then

$$(\sigma_{dN})_m = \frac{P_{max} \sin\alpha}{\pi (D_m - t_o)\, t_o} \quad \ldots \quad \ldots \quad (27)$$

Using the definition

$$C_j = \frac{D_m - t_o}{D_s + t_o} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (28)$$

where D_s = diameter of the punch
and with the aid of formula (3), the nominal stress at the punch diameter

$$(\sigma_{dN})_s = \frac{P_{max} \sin\alpha}{\pi (D_s + t_o)\, t_o} \quad \ldots \quad \ldots \quad \ldots \quad (29)$$

Using the definition

$$C_R = \frac{D_s + t_o}{(D_s + t_o) - (2r_s + t)(1 - \sin\alpha)} = \frac{1}{1 - \frac{1}{C_s}(1 - \sin\alpha)} \quad \ldots \quad \ldots \quad (30)$$

where

$$C_s = \frac{D_s + t_o}{2r_s + t_o} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (31)$$

r_s = punch profile radius
and with the aid of formula (6), the nominal drawing stress at the maximum diameter where the material touches the punch is:—

$$(\sigma_{dN})_{rs} = \frac{P_{max} \sin\alpha}{\pi [(D_s + t_o) - (2r_s + t_o)(1 - \sin\alpha)] t_o} \quad \ldots \quad \ldots \quad (32)$$

From figure (1) it can be calculated from elementary principles that

$$\sin\alpha = \frac{B + (C_h - 1)\sqrt{(C_h - 1)^2 + (B^2 - 1)}}{(C_h - 1)^2 + B^2} \quad (33)$$

where

$$C_h = \frac{h}{r_m + r_s + t_o} \quad \ldots \quad \ldots \quad \ldots \quad (34)$$

$$B = 1 + \frac{D_m - D_s - 2t_o}{2(r_m + r_s + t_o)} \quad \ldots \quad \ldots \quad (35)$$

h = travel of the punch or height of the product.
r_s = die-profile radius.

APPENDIX II

Because the maximum punch load P_{max} may be written as a sum of forces, *viz.*

$$P_{max} = P_H + P_s + P_{b_1} + P_{b_2} + P_F$$

the magnitudes mentioned in formula (1) may be defined as follows:

(a) $$C_H = \frac{P_H \sin\alpha}{\pi (D_m - t_o)\, t_o} = (\mu_1 + \mu_2)\frac{H}{\pi (D_m - t_o)\, t_o} = (\mu_1 + \mu_2)H_o \quad (36)$$

where P_H is the part of the punchload which is necessary to supersede the friction at the flange.

Normally it is assumed that all the blankholder load H due to thickening is exerted on the extreme edge of the sheet.

H = blankholder load

μ_1 and μ_2 = coefficient of friction occurring at both sides of the sheet

H_o = specific blankholder load related to the section at the die-boring.

(b) $$S = \frac{P_s/\sin\alpha}{\pi (D_m - t_o)\, t_o}$$

where P_s is the part of the punch load necessary to draw the flange within the die-boring.

(c) $$b_1 = \frac{P_{b_1}/\sin\alpha}{\pi (D_m - t_o)\, t_o}$$

where P_{b_1} is the part of the punch load necessary to bend the flange material locally $(R_m + r_m)$ around the die-profile

$R_m = \frac{1}{2} D_m$

r_m = radius of the die-profile.

(d) $$b_2 = \frac{P_{b_2}/\sin\alpha}{\pi (D_m - t_o)\, t_o}$$

where P_{b_2} is the part of the punch load necessary to rebend the material at the die-profile.

(e) $$F = \frac{(P_H + P_s + P_{b_1})/\sin\alpha}{\pi (D_m - t_o)\, t_o} = \frac{P_F/\sin\alpha}{\pi (D_m - t_o)\, t_o}$$

or

$$F = \frac{P_F}{P_H + P_s + P_{b_1}}$$

where P_F is the part of the punch load necessary to overcome the friction when sliding of the material across the die-profile occurs.

For application of the calculations by Chung and Swift, the magnitude b_2 must be converted to true stress at the shortest radius where the material still touches the die and b_1 to true stress at $(R_m + r_m)$. When b_{1w} and b_{2w} are the true stresses, then:—

$$b_{1w} = \frac{D_m - t_o}{D_m + 2r_m} \frac{t_o}{t_1} b_1 \qquad .. \quad .. \qquad (37)$$

$$b_{2w} = \frac{D_m - t_o}{D_m - t_2} \frac{t_o}{t_2} \frac{1}{1 + \frac{2r_m + t_2}{D_m - t_2}(1 - \sin\alpha)} b_2 \qquad (38)$$

where

t_1 = true sheet thickness prior to bending.

t_2 = true sheet thickness prior to re-bending.

It follows from the investigations of Chung and Swift that the drawing stresses due to bending, with respect to unbending, are

$$b_{1w} = \frac{2}{1 + 2\, r_m/t_1}\, \bar{Q}_1$$

$$b_{2w} = \frac{2}{1 + 2\, r_m/t_2}\, \bar{Q}_2$$

where $\bar{Q}$ = function which mainly depends on the representative yield stress at bending with respect to unbending.

It follows from the investigation by Chung and Swift that the difference in thickness between bending and unbending is in general small, so that in good approximation $t_2 = t_1 = t$.

Furthermore the difference between the variables on which $\bar{Q}_1$ and $\bar{Q}_2$ depends is not large, so that a good approximation is $\bar{Q}_2 = \bar{Q}_1 = \bar{Q}$. Consequently the drawing stress due to bending and unbending is

$$b_{1w} = b_{2w} = \frac{2}{1 + 2\, r_m/t}\, \bar{Q}$$

Due to the increase in thickness and the yield stress of the flange material when the drawing process proceeds, b_{1w} and b_{2w} increase. The thickness varies from

$$0.9\, t_o \leqslant t \leqslant 1.4\, t_o$$

The mean thickness is therefore $\bar{t} = 1.15\, t_o$.

At maximum punch load, which technically speaking is important only, the real sheet thickness will not deviate much from the mean thickness $\bar{t}$. It is therefore by all means justified to choose the constant value $1.15\, t_o$ for t_1, so that $\frac{2}{1 + 2\, r_m/t_o}$ in formula (39) may be approximated at

$$C_b = \frac{2}{1 + 1.75 C_r} \qquad .. \quad .. \quad .. \qquad (40)$$

where

$$C_r = r_m/t_o \qquad .. \quad .. \quad .. \quad .. \qquad (41)$$

One should be careful, however, when the die-profile ratio C_r becomes small. Then thinning due to bending may play an important part and largely determine the deep-drawing capacity, as is pointed out in 3.2.b. Particularly the thinning of the non-workhardened material at the beginning of the deep-drawing process has very much influence. According to formulae (37) up to (41) the nominal stresses b_1 and b_2 are

$$b_1 = \frac{D_m + 2r_m}{D_m - t_o} \frac{t}{t_o} C_b \bar{Q} \qquad .. \quad .. \qquad (42)$$

$$b_2 = \frac{D_m - t}{D_m - t_o} \frac{t}{t_o} \left[1 + \frac{2r_m + t}{D_m - t}(1 - \sin\alpha)\right] C_b \bar{Q} \qquad (43)$$

Consequently

$$C_{m b_1} + b_2 = C_b Q \qquad .. \quad .. \quad .. \qquad (44)$$

where

$$C_b^* = 1.15 \left(1 - \frac{0.15}{C_f (D_s/t_o + 1)}\right) \left[(C_m + 1) C_b + \frac{2.3 (C_m + 1 - \sin\alpha)}{C_f (D_s/t_o + 1) - 0.15}\right]$$

In general $\sin\alpha = 1$. Furthermore for the majority of testing tools C_f is only a few per cent

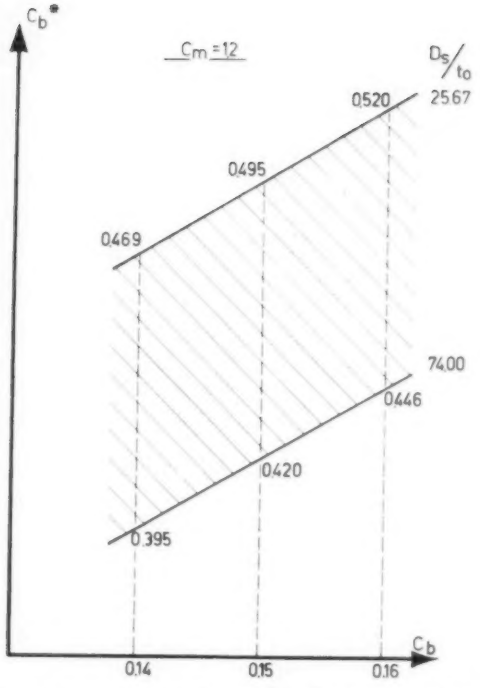


Fig. 7.—True profile parameter C_b^* as a function of the die profile parameter C_b

larger than 1, whereas D_s/t_o often varies between 25 and 75. Therefore the following is a very good approximation:

$$C_b^* = 1.15\,(C_m + 1)\,C_b + \frac{2.64\,C_m}{C_f\,(D_s/t_o + 1) - 0.15} \qquad (45)$$

this means that for constant values of D_s/t_o, C_f and C_m, C_b^* is a linear function of C_b. For tools where

$$1.030 < C_f < 1.040$$
$$74 > D_s/t_o > 25.67$$

C_b^* lies in the interval:—

$0.034\,C_m + 1.15\,(C_m + 1)\,C_b < C_b^* < 0.096\,C_m + 1.15\,(C_m + 1)\,C_b$.

Fig. 7 gives a pertinent schematic presentation for practical values of C_b. (0.14 up to 0.16).

The values mentioned near the points are valid for $C_m = 1.2$. All the C_b^*-values lie in the hatched area. The width of this area is $0.062\,C_m$. For the practical value $C_m = 1.2$ the width is therefore 0.074, which means that at constant C_b the values of C_b^* lie in an interval whose limits have a maximum deviation of approx. ± 8 per cent from the average value. By using a constant punch diameter for different sheet thicknesses, the value of C_b^* therefore changes, although C_b is kept constant.

In order to ensure that the test is independent of the tool dimensions C_b^* must be kept constant instead of C_b.

This means that

$$r_m = 0.575\,t_o \left[\frac{2.3\,(C_m + 1)\,C_f\,(D_s/t_o + 1) - 0.345\,(C_m + 1)}{C_b^*\,C_f\,(D_s/t_o + 1) - (2.64\,C_m + 0.15\,C_b^*) - 1} \right] t_o \qquad (46)$$

must be satisfied, instead of

$r_m = C_r t_o$ where C_r = constant.

For a given interval of D_s/t_o and C_f and for a given friction at the die-profile, the value of C_b^* must so be chosen that r_m/t_o lies in a favourable interval. For practical values of $C_m = 1.2$ $1.030 < C_f < 1.040$ and $C_b^* = 0.44$ it is found that in the interval $74 > D_s/t_o > 25.67$

r_m/t_o varies from

$$6.75 < r_m/t_o < 8.03.$$

This therefore means that at constant punch diameter, the ratio r_m/t_o must increase with increasing sheet thickness. The total deviation from the average value 7.4 is therefore ± 9 per cent.

In the experiments, the profile radius of the die had first of all been so chosen that it was independent of the ratio of the punch diameter- and the sheet-thickness. This was done, because in formula (6) the bending at the die occurs as an additive term $C_b^*\overline{Q}$ and the contribution to the drawing stress is not so large as that of the drawing-in stress S and the friction.

Moreover the function $\overline{Q}$ is particularly dependent on the yield point of the material at the die-profile.

In the first approximation it may be assumed that $\overline{Q}$ is a linear function of the mean representative yield stress of the sheetmaterial at the die-profile. As the process progresses, the representative yield stress increases so that $\overline{Q}$ increases about linearly with it. The absolute value and the increase of the yield stress depend on the nature of the sheet material, so that $\overline{Q}$ is largely determined by the properties of the material, whereas C_b^* has more the character of a geometrical quantity.

APPENDIX III

As was explained in Appendix I, the angle between the cup wall and the plane of the blank-holder is given by formula (33). According to formula (35) the magnitude B may be written as

$$B = 1 + \varepsilon$$

where

$$\varepsilon = \frac{D_m - D_s - 2t_o}{2\,(r_m + r_s + t_o)} = \frac{C_s\,(C_f - 1)}{1 + \dfrac{C_s\,(2C_r + 1)}{D_s/t_o + 1}}$$

For a normally used set of testing tools the following holds for example:—

$1 < C_s < 5$

$C_r = 7$

$1.030 < C_f < 1.040$

$74 > D_s/t_o > 25.67$

so that for this set ε lies in the interval

$0.02 < \varepsilon < 0.09$.

When cup height $h = r_m + r_s + t_o$ is this means when $C_h = 1$, then

$$\sin\alpha = \frac{1}{B} = 1 - \varepsilon$$

so that

$0.98 > \sin\alpha > 0.91$.

When the cup height $h = 2\,(r_m + r_s + t_o)$ this means when $C_h = 2$, then

$$\sin\alpha = \frac{2B}{1 + B^2} = \frac{1}{1 + \dfrac{\varepsilon^2}{2\,(1 + \varepsilon)}}$$

$$= 1 - \frac{\varepsilon^2}{2} + \frac{\varepsilon^3}{2}$$

so that $\sin\alpha$ now lies in the interval

$0.9998 > \sin\alpha > 0.9963$

so that consequently for the tools described above always $\sin\alpha > 0.99$ when $C_h > 2$.

For the cup height ratio $C_h = 2$ the following holds

$$\sin\alpha = \frac{2B}{1 + B^2} = \frac{1}{1 + \dfrac{\varepsilon^2}{2\,(1 + \varepsilon)}}$$

In order to ensure that when $C_h = 2$, $\sin\alpha$ lies in the interval

$1 > \sin\alpha > 0.99$

ε must lie in the interval

$0 < \varepsilon < 0.1526$

and consequently C_f must lie in the interval

$$1 < C_f < 1 + 0.1526 \left(\frac{1}{C_r} + \frac{2C_r + 1}{D_s/t_o + 1} \right) \qquad (47)$$

* * *

LIST OF SYMBOLS

$B = 1 + \dfrac{D_m - D_s - 2t_o}{2\,(r_m + r_s + t_o)}$

$C_b = \dfrac{1}{1 + 1.75\,C_r}$ = die-profile-parameter

$C_b^* = 1.1\,(C_m + 1)C_b + \dfrac{2.64\,C_m}{C_q\,(D_s/t_o + 1) - 0.15}$

= true die-profile parameter

$C_H = (\mu_1 + \mu_2)\,H_o$ = flange friction parameter

$C_h = \dfrac{h}{r_m + r_s + t_o}$ = cup height-ratio

$C_m = F + 1 \approx 1 + \mu_m\alpha$

= die-profile-friction-parameter

$C_q = \dfrac{D_m - t_o}{D_s + t_o}$ = clearance parameter

$C_r = r_m/t_o$ = die-profile-ratio

$C_R = \dfrac{1}{1 - \dfrac{1}{C_r}\,(1 - \sin\alpha)}$

= cup tapering-parameter

$C_s = \dfrac{D_s + t_o}{2r_s + t_o}$ = punch-profile-parameter

D = blank diameter

$D_F = D - (D_m - t_o)$ = flange to be drawn

$D_H = D - (D_m + 2r_m)$

= flange under blankholder load

D_k = limiting blank diameter

D_m = die-bore-diameter

D_s = punch diameter

$F = \dfrac{P_f}{P_H + P_s + P_{bl}} \approx e^{\mu_m\alpha} - 1 \approx \mu_m\alpha$

(*Continued in page* 803)

APPENDIX IV

TABLE XII—Test conditions *The following are the results of measurements, which have been represented in Figs.* 1 *to* 6.

	Sheet	t_o mm	D_s mm	r_s mm	D_m mm	r_m mm	H kg	q	Lubricant	C_q	H_o kg/mm²	C_r	C_b	C_s
I	Steel SEDD	1.03	50.0	4.53	53.89	6.8	*	0.89	Garia 31	1,036	*	6.60	0.159	5.06
II	Brass 63/37	0.81	50.0	4.73	53.38	6.0	*	1.09	Garia 31	1,035	*	7.41	0.143	4.95
III	Steel EDD	0.76	25.0	2.16	27.46	5.4	*	0.62	Garia 31	1,037	*	7.11	0.149	5.07
IV	Steel EDD	0.76	50.0	4.73	52.63	*	1,240	0.73	Garia 31	1,022	10.0	*	*	4.97
V	Steel	0.505	50.0	6.1	52.63	*	830	1.60	Garia 31	1,032	10.0	*	*	3.97
VI	Brass 63/37	0.61	50.0	4.73	52.63	*	1,000	1.16	Garia 31	1,028	10.0	*	*	5.03
VII	Steel SEDD	1.03	50.0	*	53.89	6.8	1,690	0.89	Garia 31	1,036	10.0	6.60	0.159	*
VIII	Brass 63/67	0.81	50.0	*	53.38	6.0	1,340	1.09	Garia 31	1,035	10.0	7.41	0.143	*
IX	Steel EDD	0.76	50.0	4.73	*	5.1	—	—	Garia 31	*	10.0	6.70	0.157	4.96
X	Steel EDD	0.98	50.0	6.1	*	5.0	—	—	Garia 31	*	10.4	5.10	0.201	3.87
XI	Brass 63/67	0.81	50.0	4.73	*	5.1	—	—	Garia 31	*	10.0	6.30	0.166	4.94

Investigations on the Swift Cupping Test

(*Continued from page* 802)

H = blankholder load

$H_o = \frac{H}{\pi (D_m - t_o) t_o}$ = specific blankholder load related to the section at the die-bore

P = punch load

P_{max} = maximum punch load

P_{b1} = part of punch load necessary to bend the flange material around the die-profile

P_{b2} = part of punch load necessary to rebend the material at the die-profile

P_F = part of punch load necessary to overcome the friction at the die-profile

P_{fl} = part of punch load necessary to supersede the friction at the flange

P_s = part of punch load necessary to draw the flange within the die-boring

Q = stress-function which describes the bending unbending at the die-profile

$R = \frac{1}{2}D$ = half of the blank diameter = blank radius

S = stress at the die-boring to effect the pure drawing-in of the flange

$T_{Fm} = \frac{D_F}{D_m - t_o}$ = cupfoot flange drawing ratio = cupfoot-FDR

$T_k = \frac{D_k}{D_s}$ = conventional limiting drawing ratio = LDR

$T_{kFm} = \frac{D_{kF}}{D_m - t_o}$ = cupfoot-limiting flange drawing ratio = cupfoot-LFDR

$T_{km} = \frac{D_k}{D_m - t_o}$ = cupfoot-limiting drawing ratio = cupfoot-LDR

$T_{ks} = \frac{D_k}{D_s + t_o}$ = cuphead-limiting drawing ratio = cuphead-LDR

b_1 = drawing stress at die-boring to carry out the bending around the die-profile

b_2 = drawing stress at die-boring to effect the rebending at the die-profile

h = height of the cup or punch-travel

$q = \frac{D_m - D_s - 2t_o}{2t_o}$ = percentage of filled clearance

r_m = die-profile-radius

r_s = punch-profile-radius

t_o = sheet-thickness

α = angle between cupwall and the plane of the blankholder

ε = B–1

μ_1 and μ_2 = coefficients of friction at both sides of the flange

μ_m = coefficients of friction at the die-boring

$(\sigma d_N)_m$ = nominal drawing stress at the die-boring

$(\sigma d_N)_s$ = nominal drawing stress at the punch-diameter

$(\sigma d_N)_{rs}$ = nominal drawing stress at the largest-diameter where the material touches the puncn-profile

The Importance of the Steel Stockholder

(*Continued from page* 786)

the steelmaker and, indeed, of the nation itself, that the steel stockholder service should be more fully, more regularly, and more *realistically used.*

Summary

The facilities offered by the modern steel stockholder service are of great *and growing* importance to Britain's economy, since they offer the steel user a sound, financially attractive and highly convenient alternative to the cumbersome and costly practice of holding stocks of steel in excess of immediate production requirement.

It should never be overlooked that the steel stockholder service offers to industry, and to the nation as a whole, the only really effective answer to one of the gravest problems facing steel to-day—that of maintaining a realistic flow of supply and demand to keep production flowing.

OIL ADDS TO BLAST-FURNACES' EFFICIENCY

BLAST-FURNACE performance can be improved considerably by the injection of oil. This has been proved at the Ebbw Vale Works of Richard Thomas and Baldwins Ltd., where the first full-scale experiments carried out in Great Britain on this technique started early this year. During a six-months' trial period analysis of the results obtained showed advances in outputs, quality and general furnace performance, which justify retention of the system. Two methods of injection have been tried, through stainless-steel lances and also specially designed tuyeres and experiments are continuing to decide the most effective techniques and further improvements are anticipated.

Briefly, the installation consists of small-bore feed pipes to each tuyere or lance, pumps to maintain the oil pressure, and a bulk-storage, heating and circulating system.

The injection of oil in this lower zone of the furnace provides a very efficient method of reducing the iron oxides of the ores to the metallic state and reduces the quantity of prime metallurgical coke charged to the furnace.

The new development does not mean that oil can replace coke completely—coke is still an essential part of the burden and large quantities are still needed.

What it does mean, is that the life of high quality coking coalfields is extended and that furnaces equipped for oil injection can operate more economically and so enable a Works to be more competitive.

The Control of Sheet Hardness by Extensiometer

By A. REEVES

IN the production of steel sheet and tinplate it is necessary to take frequent measurement of surface hardness. It is usual in America to use the Rockwell hardness test, this being a spot check which entails either stopping the mill to take samples or reducing the plant to very slow speeds.

Surface hardness is directly related to elongation when strip is cold rolled in a reduction or temper-pass mill, and this extension can also be used for determining the quality of the product. The advantage of this method is that elongation determination can be used as a continuous measurement which does not slow down production; it is therefore ideal for quality control of temper-mill products. Elongation measurement is suitable for mills over a range of 200 to 8000 ft. per minute.

Measurement Technique

Digital instrumentation is a very reliable and accurate technique for this purpose. Systems can be built which are readily adaptable to different dimensions in the material to be measured; in temper mills very small elongations, as little as 0.5 per cent. or 0.062 in. per 12.5 in., can be recorded, and the equipment can be compensated rapidly for changes in roll diameters, gear ratios, etc. As can be seen from the illustration (Fig. 1), which shows a control cabinet for a high-speed two-stand tin-plate temper mill, the equipment takes a minimum of space.

The Extensiometer

A new digital extensiometer is now available from Allis-Chalmers of Milwaukee, Wisconsin. It is an all static system which measures the strip elongation as it passes through the reduction mill work rolls. The equipment computes and displays continuously the elongation as a percentage. There are four methods of display: analogue indication using a deflexion instrument, digital indication using numerical display, continuous recording on a strip chart, and numerical storage using a tape printer.

Elongation measurement is accomplished with two magnetic pulse generators geared to contact rolls at the entry and exit of the mill. The generators transmit impulses at a rate proportional to the rotation speed of the contact rolls; this means that

Fig. 1.—An Allis-Chalmers control cabinet for a high-speed two-stand tinplate temper mill

impulses are emitted more rapidly from the exit roller where the sheet is thinner.

Computation of tension is accomplished by counting the number of pulses produced by the exit roll generator during the time required to accumulate a predetermined number of pulses from the entry roll.

Pulse Function

Using the equations (given below) the predetermined number of pulses from the entry roll can be calculated; the figure is a function of the entry and exit roll diameters.

Equation 2 can be solved by using a pair of digital counters. One of these counters is of the preset type and is used to accumulate the pulses from the entry generator up to a value of $C_1 = 1000$; the other counter accumulates the pulses from the delivery side. When the entry counter reaches 1000 a signal stops the count at exit; then for a count of C_1 at entry the delivery counter will have accumulated a count of $C_2 = 1000\ (1+E)$.

If the elongation has been 1 per cent. then $C_2 = 1000\ (1+0.01) = 1010$ in which 10 pulses in excess of 1000 are equivalent to a 1 per cent elongation. To obtain greater accuracy, and to overcome unavoidable phase shifts in the system, the count C_1 can be set to 10,000 so that 10,100 or 100 pulses in excess of C_1 represents 1 per cent.

Because the elongation can be obtained directly from reading the last three least significant digits of the delivery counter, the reading can be presented

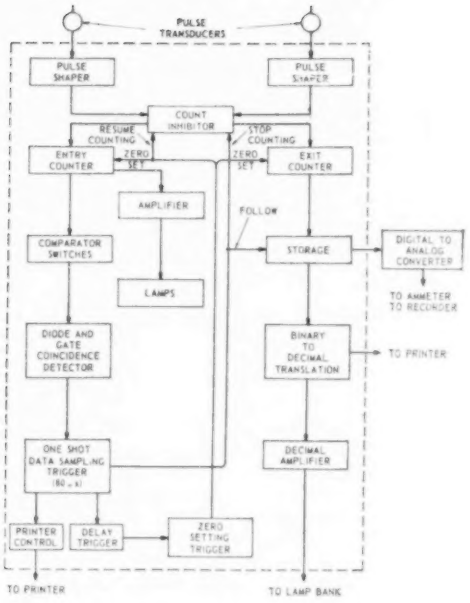


Fig. 2.—Diagram of control system. Pulse generator signals of delivery side of mill are counted and compared to entry-side signals to provide control, continuous record, analogue and digital indication and numerical storage

after conversion in any of the four forms listed above.

Derivation of Pulse Function

Let:

x_1, x_2 = Incremental length of strip passing over the entry and delivery contact rolls for every pulse produced by the pulse generators.

C_1, C_2 = Total number of pulses to be accumulated on a given time.

L_1, L_2 = Total length of strip measured during the time that counts C_1, C_2 took place.

N_1, N_2 = R.p.m. of entry and exit rolls.

D_1, D_2 = Diameter of entry and exit rolls.

V_1, V_2 = Incoming and outgoing strip speed.

R_1, R_2 = Gear ratio between contact roll and pulse generator.

F_1, F_2 = Pulses per revolution of pulse generators.

Then:

$$L_1 = x_1 \cdot C_1 \quad .. \quad .. \quad .. \quad .. \quad .. \quad (1)$$

$$L_2 = x_2 \cdot C_2 \quad .. \quad .. \quad .. \quad .. \quad .. \quad (2)$$

We can also write the following relations:

$$L_2 = L_1 + E \cdot L_1 \quad .. \quad .. \quad .. \quad .. \quad (3)$$

Where: E = percentage elongation of strip.

Manipulation of equations (1), (2) and (3) yields:

$$x_2 \cdot C_2 = x_1 \cdot C_1 (1 + E)$$

$$C_2 = \frac{x_1}{x_2} \cdot C_1 (1 + E) \quad .. \quad .. \quad .. \quad (4)$$

Assume that the count to be selected on entry roll C_1 is:

$$C_1 = 10^n \cdot \frac{x_2}{x_1} \text{ (where } n = 2, 3, \text{ etc.)} \quad .. \quad (5)$$

The values of x_1 and x_2 can be derived from the dimensions of the entry and exit rolls as follows:

$$x_1 = \frac{\pi \cdot D_1}{R_1 \cdot F_1} \quad .. \quad .. \quad .. \quad .. \quad .. \quad (6)$$

$$x_2 = \frac{\pi \cdot D_2}{R_2 \cdot F_2} \quad .. \quad .. \quad .. \quad .. \quad .. \quad (7)$$

Substituting in equation (5):

$$C_1 = \frac{D_2 \cdot R_1 \cdot F_1 \cdot 10^n}{D_1 \cdot R_2 \cdot F_2} \quad .. \quad .. \quad .. \quad (8)$$

In practice, the gear ratios R_1 and R_2 and the pulse generators at the entry and exit side of the mill are normally the same (not necessary however) which further simplifies equation (8) to:

$$C_1 = \frac{D_2 \cdot 10^n}{D_1} \quad .. \quad .. \quad .. \quad .. \quad (9)$$

The diameters of the entry and exit rolls often differ due to uneven wear or necessary grinding needed to remove marks developed during rolling. However, in the case of the digital extensiometer, this condition does not represent a maintenance problem since, as shown in equation (9) all that is required to retain system accuracy is to compute a new ratio $\frac{D_2}{D_1}$ every time the diameter of either roll changes.

Eq. (9) (the pulse count to be established at the entry side of mill) includes a factor 10^n in which the exponent n is to be selected as 2, 3, etc. Substitution of equation (9) into (4) gives:

$$C_2 = 10^n (1 + E) \quad .. \quad .. \quad .. \quad .. \quad (10)$$

Assume that at the start of a rolling operation the diameters of the entry and exit rolls are the same $\left(\frac{D_2}{D_1} = 1\right)$ and $n = 3$ therefore

$$C_2 = 1000 (1 + E) \quad .. \quad .. \quad .. \quad .. \quad .. \quad (11)$$

The Extensiometer Components

In the extensiometer illustrated diagramatically in Fig. 2, 180 electrical impulses per revolution of the input shaft have been chosen. Two five digit counters, preset and display, are connected to the entry and delivery generators. Five comparator switches are used to store the precalculated count C_1, and also to establish the level for a coincidence detector to activate a one-shot data sampling trigger when the count C_1 has accumulated in the entry counter. When the data sampling pulse is initiated a count inhibitor prevents any further accumulation of pulses in both counters; at the

(*Continued in page* 807)

The Effect of ADDITIONS TO ZINC ON ITS FLUIDITY

A REPORT OF RECENT RUSSIAN WORK

By D. G. MORGAN*

IT has been shown[1, 2] that the presence of lead in zinc gives better flow properties of the zinc from the surface during galvanizing, while other investigations[3, 4] show that the zinc coating is then increased in thickness. It has been suggested[2] that the addition of tin to zinc reduces its viscosity and that the weight of the coating increases with the tin content.

In all the above investigations, the change in viscosity of the molten zinc and the increase in coating thickness are both due to an accumulation of crystals of iron-zinc metallides in the molten metal, and this also produces incrustations and rough areas on the coating[5]. These ill-effects of the iron-zinc metallides on the wetting of the steel by the zinc are eliminated by adding lead to the galvanizing bath; the addition of aluminium to the bath also has a good effect, but impairs the evenness of the coating.[6].

The zinc coating on sheet steel and other products begins to harden from the outside, while the layer adjacent to the steel retains some accumulated heat and continues to flow under the static head of metal. The longer this state lasts, the less zinc is taken from the bath; under certain conditions, depending upon the viscosity of the molten metal, its surface tension and interphase tension and the nature of the crystallization process, the molten zinc will cease to flow. Since these factors are largely determined by the composition, the effects of additions to the zinc on the formation of the coating and on the consumption of zinc in the galvanizing of steel are characterized by variations in the flow properties of the molten metal.

Recent Russian work[7] on the flow properties of zinc containing various additions is therefore of interest, and a brief account of this work is given below. Unfortunately, no details are given of the method used to measure the ability of the metal to flow, the results merely being quoted as the fluidity,

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Fig. 1.

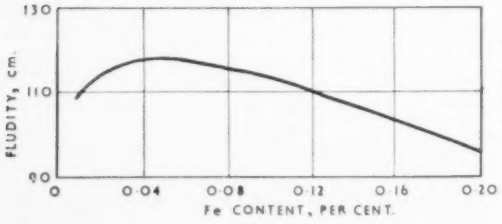
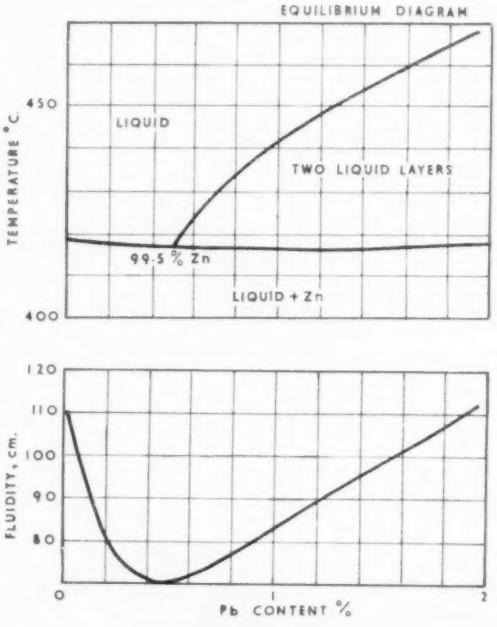


Fig. 2.



Additions to Zinc

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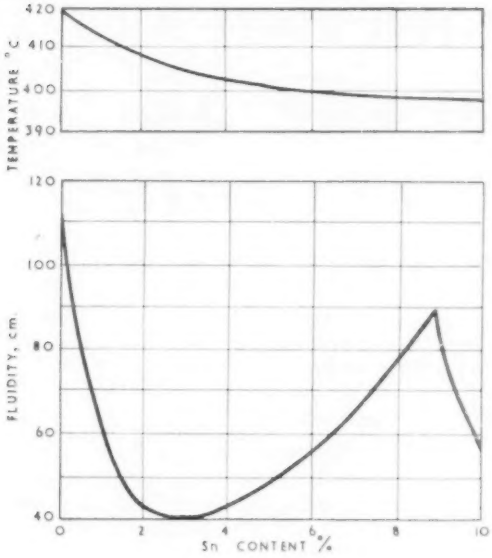

Fig. 3.

measured in cm., but the effects of the various additions are sufficiently clear from the form of the results.

Iron

The flow of zinc with various concentrations of iron is shown in Fig. 1, from which it is seen that a small concentration of iron in zinc, *i.e.*, up to about 0.07 per cent, does not change its fluidity, but that with a higher content of iron the viscosity increases.

Lead

The change in fluidity with lead content is shown in Fig. 2. The introduction of up to 0.5 per cent Pb decreases the fluidity but beyond this the fluidity is improved. The equilibrium diagram shows that if the lead content of the zinc is more than 0.5 per cent the alloy separates into layers of two immiscible liquids, so that the observed increase in fluidity can be explained by the separation of the pure zinc which has less viscosity than its alloy with lead.

Tin

With up to 2 per cent tin added to the zinc (Fig. 3) the viscosity increases, but with a tin content of 2 to 9 per cent there is a decrease, although no conversions at these tin contents occur on the equilibrium diagram of the Zn-Sn system.

Aluminium

The relationship between the fluidity of zinc and the aluminium content (Fig. 4) is related to the changes which occur in the equilibrium diagram, but the overall change in fluidity is not large.

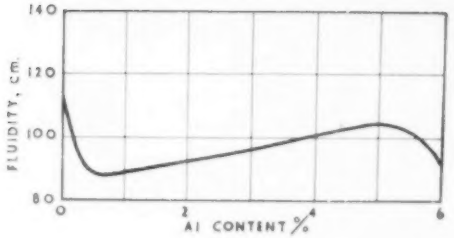

Fig. 4.

For zinc itself, the maximum fluidity is obtained for pure electrolytic zinc and an alloy of it with lead (containing more than 2 per cent Pb), so that these should be used in the galvanizing bath in order to reduce the quantity of zinc removed by the products immersed in it. It is also suggested that not more than 0.2 per cent aluminium should be added to the bath in order to suppress the growth of an intermediate layer of large iron-zinc metallides, which cause flaking of the zinc coating.

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The Control of Sheet Hardness by Extensiometer

(*Continued from page* 805)

same time the count inhibitor switches a three digit transistor storage matrix to its "follow" mode to read out the three least significant digits of the exit counter. Several microseconds are allowed for the reading to be sorted in the matrix before a one-shot zero setting trigger resets both counters to zero and releases the count inhibitor to start accumulating a new count.

The stored reading is reset translated to decimals for presentation in a three digit lamp bank and is converted to analogue form to operate a deflexion instrument or a recorder if required. Printer command and printer operation can also be incorporated. An important feature of the system is that the information stored in the transistor matrix is displayed continuously during the time a new count is being made.

As has previously been explained, by using high powers of ten to set the entry count, the percentage elongation can be read to greater accuracy, but this will require greater lengths of strip to accumulate the count; to compensate higher counting rates can be employed.

It is considered feasible to use the digital extensiometer for closed-loop type control systems.

The Production of a

DEEP-DRAWN COVER FOR AN ELECTRIC MOTOR

By "TARENTFORD"

THE drawing of the electric-motor cover shown in Fig. 1 shows that the final piercing stages will present some problems in the design and construction of any necessary tools for the workstages, and that the machining of a series of apertures to locate the die inserts for the 24 elongated slots, provides an expensive though not impossible problem to overcome.

Consideration of this point was carefully weighed against the fact that the slots only represent a cooling medium to the motor and have no dimensional accuracy, and it was decided that a solid type of die would have the necessary degree of strength and that correction of a distorted die after heat treatment could be easily overcome by grinding the slots on a jig grinder. Tool construction was undertaken with these points in mind, and the blank cut to 11 in. dia. from 22-gauge material, on a circle cutting machine.

The first draw, shown in Fig. 1, produced a shell approximately 6¼-in. dia. and was accomplished on a double action press using the tool in Fig. 2. The die A, blank holder C, and top plate D presented a problem in manufacture since the diameters indicated that forgings were essential before rough turning could proceed. This also meant that the diameter of the die could accommodate the locating pins for the blank instead of reducing its diameter as is more usual with parts of this kind, and to make some form of separate location. This solution would probably need another forged ring or a series of pins inserted in the bolster and standing high enough to match the top surface of the die.

The die follows conventional practice and location is made from the outside diameter in preference to using dowels as a means of positioning it on the lower bolster H. Assembling the locating pins B to the die also means that the flats forming the recess into which the blank is dropped are ground

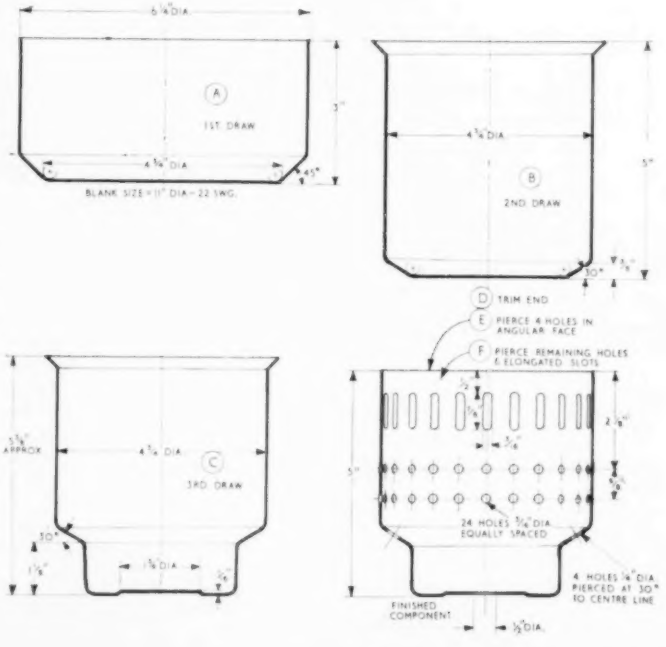


Fig. 1.—The drawn cover seen at the bottom right hand corner of this illustration has the rather unusual characteristic of requiring holes punched in three directions, vertically, horizontally and angularly making a total of 77 holes, presenting quite a problem when the manufacture of the final tools was undertaken

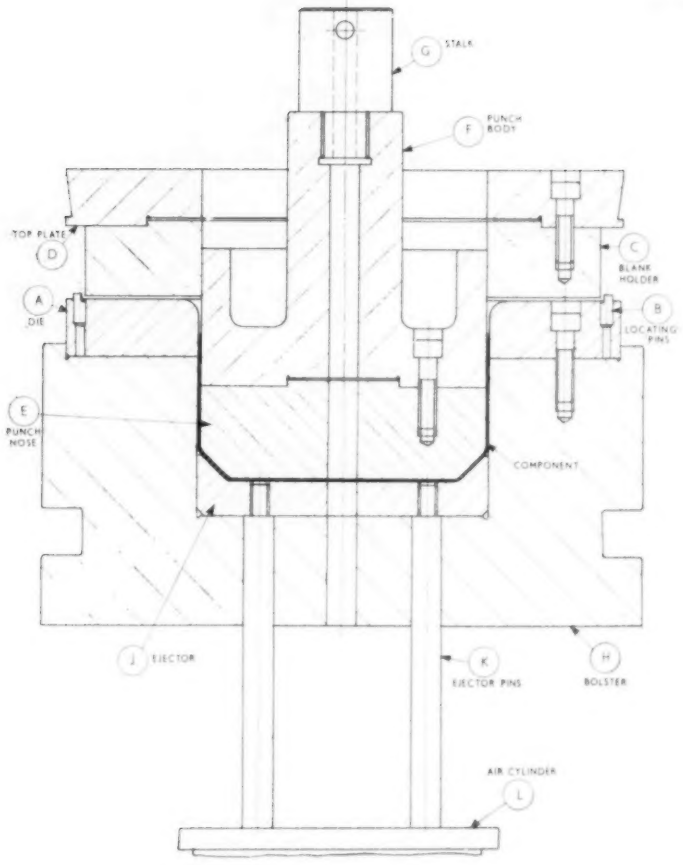


Fig. 2.—A large double-action tool transformed the flat blank to a comparatively deep shell, and its manufacture presents few machining problems. In this case the locating pins were inserted in the die rather than provide a separate set of pins. The die was, however, a forging and not cut from bar material

at the same setting as the draw diameter, radius and top surface, achieving a concentric setting of each blank.

Bolsters for deep-drawing tools are usually large; a casting with adequately ribbed side walls is one method of providing the required strength to overcome bursting, but for a shell some 6 in. dia., a solid piece of iron is easier to cast as it does not need a complicated pattern and core box. This method was used for the bolster H and a groove was afterwards turned round the periphery to make a clamping ledge to hold it to the press bed.

The upper details require little explanation; the top plate D was recessed to locate the blank holder C and the surface case hardened to resist the heavy wear associated with this work.

A two-part punch and body, details E and F, were a feature of the upper operating member, the former hardened on all working surfaces. The spigot and recess method was applied to locate both parts and a hole through the centre ensured that both could be rotated between centres on a rotary grinding machine to match the outside diameter. The outside diameter of F was also case hardened as there is a risk of scoring taking place and rendering the punch body useless. The introduction of the stalk G allows the transfer of an operation from one press to another which may require a larger or smaller location for the press ram.

The final details J, K and L are required to remove this deep shell from the lower tool and the use of air is essential for the deeper type of draw. The ejector is shaped to form an angular bottom surface of a blank, and corresponds to the diameter of the next shell. Reference to Fig. 1 explains this and it will be seen that the diameter of the lower radii is equal to the inside diameter of the second drawn shell.

An identical tool is illustrated at Fig. 3 which further reduces the diameter of the shell leaving an angular rim round the top edge which is subsequently trimmed off at a later stage. Again a two-part punch construction is attempted despite the long bolts needed to hold them together.

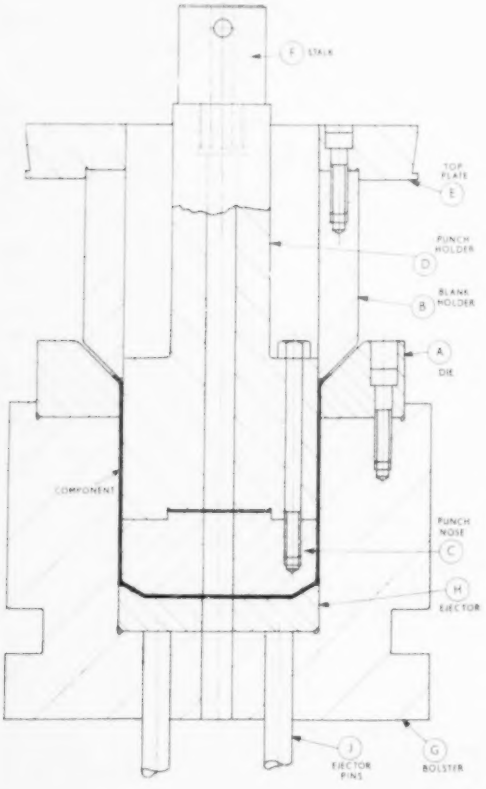
The third draw reduces the shell for about a quarter of the length, clearly seen in both Figs. 1 and 4.

As the component does not push completely through the die, the top surface is angled to form that portion of the surface on the workpiece. The punch gives a firm blow as the bottom of the stroke is reached and so sets the angle correctly. A recess is formed by the ejector H which performs the dual role of acting as the bottom of a cavity and also pushing the shell upwards on the return stroke. The punch is again a two-part assembly

though in this instance the length and small diameter made the problem a little awkward to solve. The centre portion of D is turned away to make a dumb-bell shape and this is made sufficiently long to allow three screws to secure the punch nose in place. Apart from this the design follows closely that seen in the other draw tools.

Trimming a circular blank is easily and satisfactorily performed on a trimming lathe (Fig. 5); the work is also possible on a press, but tool expenditure is much less and therefore worth serious consideration when comparatively small quantities are needed. The shell is located over three segments A when the latter are in the "collapsed" position and held laterally against the end face of the spindle D by a rotating rear support G. Two circlips B hold the segments together, and a retraction of the centre spindle D toward the machine head, causes the segments to expand and securely grip the shell. Tapering the rear member C and the spindle mentioned above, provides the expanding medium

Fig. 3.—Following closely on the lines of the previous tool, the second draw again presented no problems. A separate punch nose is used instead of specifying a solid detail for this member



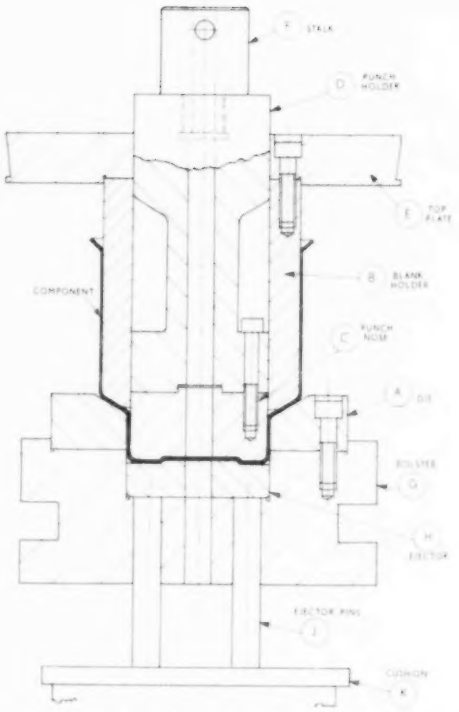


Fig. 4.—Drawing the bottom cavity and raising the boss meant the parts did not pass completely through the die aperture; in fact the greater part of the previous draw remains and is supported by the long blank holder

and ensures a firm grip on the shell adjacent to where the cut is taking place. The trimming tool F performs the operation and the ring is easily removed when the segments are released.

Two piercing operations were considered necessary for this component rather than attempt the work at a single blow of the press. Two factors influenced this decision. It avoided trying to seat on both the angular surface and the raised impression in the bottom of the shell. It was immaterial which set of holes were pierced first, but as those through the side walls would throw a slight burr, the punching of four angular holes before attempting the more numerous array, means the loading is accomplished without the tendency of a shell to become tight on the spigot.

Fig. 6 shows the main details of this angular piercing tool, and as punching occurs at what is the top end of this detail, the locating spigot A is reduced to overcome the need for a long bearing area, but this diameter is ground to suit the sliding ejecting ring D.

The chief feature of the tool is the holding plate G as this locates the punches besides pushing the shell

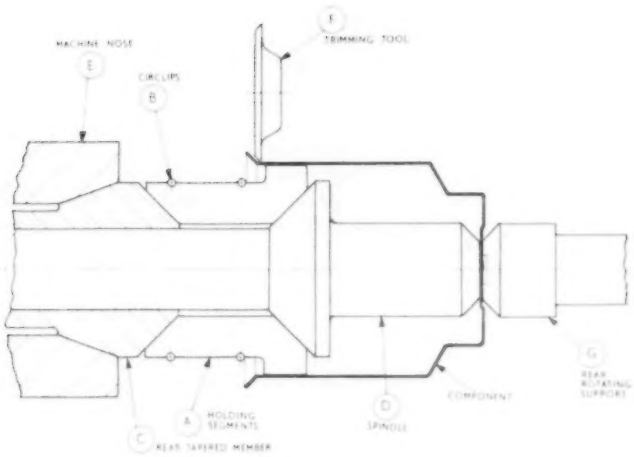


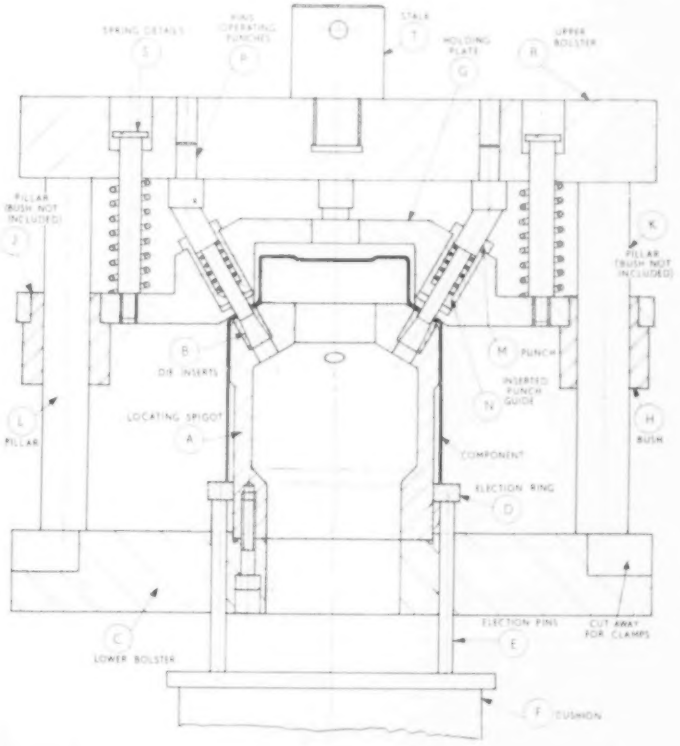
Fig. 5 (left).—Trimming on a lathe is a simple operation. Despite the apparently short locating diameter, the flat stop face against which the shell bears ensures a perfectly true rotating component

Fig. 6 (below).—Angular piercing is preferred for the initial punching stage as these leave no burr to subsequently interfere with the location of the shell. Separating the stages in this manner also overcomes the necessity of attempting to locate the workpiece on the flat surface and angular face at the same setting

down on to the angular locating face of A. The use of both the guide pillars J and K is often possible with a tool of this type and in fact provides a cheap method of ensuring that the plate slides up and down at each press stroke without having to resort to further pillars or slides on the tool. The usual spring details at S control the working of this member and ensures efficient stripping of a shell once the punches have finally withdrawn into their holders.

The holders N are essentially a refinement as continued use of this equipment naturally causes wear in the vicinity of each hole, and should be hardened if extensive application of this class of tool is envisaged. If, however, production is limited to 5,000 parts or so and costs must necessarily be kept to a minimum, then the omission of these guides is advisable, though a thickening of a plate for possible inclusion should wear take place and make substitution necessary, is a point worthy of consideration. A pin or screw will retain the punches in the guides when the top operating pin P loses contact as the ram rises. Incidentally, springs of heavier gauge than are normally deemed necessary for raising punches are included in cases where angular or side punching is practiced as they must withdraw the punches before the stripper plate G leaves the component.

The final tool, Fig. 7, has many interesting



features and in the confined space 73 holes are punched at each press stroke. Location, holding and ejection follow exactly the same lines as used in the previous tool only on this occasion the locating spigot A is not relieved to reduce the bearing surface.

The two rows of holes are side pierced by arranging the punches above each other and obtaining the motion by an angular face turned inside a ring N. Although this ring appears to be a long solid detail with the elongated punches incorporated in slots, the latter slide in another ring G while the top member acts as a retaining plate for the punches. This is necessary because of the problem of grinding the slots for these items as a jig grinder is not suitable on this occasion. Again the sloping type of face is used as a means to introduce the motion to these elongated slot punches and all holes are pierced virtually together.

Withdrawing the punches J required some degree of thought as the slots are so close together. By making the extractor L span a series of these punches, it became possible to surround the lower punch carrier G with a number of segments which operated back and forth and so retracted the punches; a large collar machined on the shaft M acted as a stop and held the extractor against the spring pressure and prevented it from being thrown clear. With so many slugs falling through the lower tool it is essential to provide adequate clearance and so overcome the problem of packing inside the cavity; here they can fall straight through and an inclinable press allows them to drop into a tray ready for removing to the scrap dump.

Only a single hole is needed in the top surface and this is effected by conventional methods; the punch does not actually cut the shell until those passing through the side walls have accomplished their task.

The die and locating spigot A presented one or two machining problems notably the grinding of the 24 elongated slots as these are actually cutting members, and though their spacing is not dimensionally important, they must correspond to the slots which appear in the ring G. Again the upper punch carrier K required the opening out of each hole as a location for the punches H, and this meant that the small holes into which the punch cutting diameter fitted, required careful boring as the tool overhang was considerable. A final skim through each hole with a multi-toothed type of cutter resembling a vertical milling tool was used piloting from the relief diameter to overcome the possibility of the tool springing slightly and causing a tight bore.

This component is typical of many where a large number of holes or slots occur and there is always an urge on the part of a designer to include all of them in a single tool rather than split the work into separate operations. The latter method is often carried too far, and serious problems and frequently scrapped details add to the cost of the equipment which can far exceed the handling necessary for a second operation. Over-elaboration in tool design raises the upkeep costs to a level above that normally

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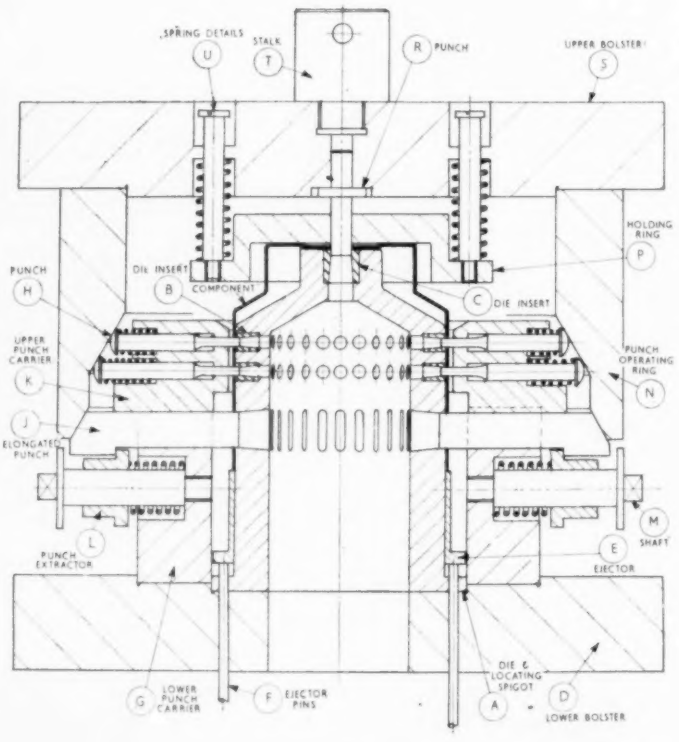

Fig. 7.—The final piercing tool is an excellent example of multi-piercing in a horizontal direction. The punch carriers are, however, separate details because of the difficulties of producing the slots and holes in which the punches slide

Quantitative Assessment of

DEEP-DRAWING and STRETCH-FORMING QUALITIES—3*

By J. C. WRIGHT, B.Sc., Ph.D., A.I.M., A.C.T. (Birm.)†

(*Concluded from page* 741, *October*, 1961)

Correlation of Non-simulative Test Results with Industrial Press Results

THE amount of information published on the correlation of non-simulative test results with industrial press results is very limited compared with comparisons of non-simulative test results with simulative tests. This is a poor reflection of the situation since it is highly likely that extensive results exist in the quality control records of many sheet users. It is probably true to say that simple tensile-test results are more useful in predicting stretch-forming performance than deep-drawing performance although more recent attention to strain ratio in the tensile test is showing considerable promise in predicting deep-drawing performance. Material undergoing a pure stretch-forming operation must be capable of considerable uniform elongation but the ability to resist local necking down is not quite so important. In pure deep-drawing, the reverse holds, in that resistance to necking down is important but the material is not called upon to undergo extensive uniform elongation. Nevertheless, a good uniform elongation reflects the ability to undergo simple plastic strain without necking down locally so that it should be a useful partial indication of deep drawing capacity. The important point is that in pure deep drawing uniform elongation is a measure of only one of the requirements whereas in stretch-forming it is the major requirement. The extent of uniform elongation depends largely on the work-hardening capacity of the material and values which assess the work-hardening capacity should also be a reasonable measure of stretch-forming capacity. The values used, apart from the uniform elongation (or total elongation to a less accurate degree) are, the proportional extent of the plastic stress range indicated by the yield stress : ultimate stress ratio, and the work-hardening coefficient, "m", explained earlier. *Knight*[54], suggests that the values of the yield : U.T.S. ratio associated with good press runs range between 0.6 to 0.65 for open-hearth rimmed steel. Aluminium-killed steels have slightly lower yield points and this is reflected in correspondingly lower values for the above ratio. A minimum requirement for uniform elongation in acceptable open-hearth rimmed steels has been found to be 22 per cent.

Failure occurs in pure deep drawing when the cup wall can no longer transmit the increasing punch load required to draw in the remaining flange from the blankholder. The deep-drawing capacity can be increased only if the strength of the cup wall can be increased relative to the required punch load. A general increase in strength from work-hardening will strengthen the cup wall but also increase the resistance of the blank to drawing in, thus increasing the necessary punch load and giving no advantage. However, *Whiteley* has demonstrated[41,42], that the punch load to fracture can be raised independently of the actual drawing load by increasing the flow strength in the plane of the sheet. Thus sheets which are anistropic in the sense that they are strongest in their thickness direction should have a greater drawing capacity than the same material in an isotropic condition. This is tantamount to saying that the material resists necking down in the thickness of the wall, and even to some extent over the radii of a partially drawn cup, which are the main criteria of failure in pure deep drawing. If a high flow strength normal to the plane of the sheet is desirable, then a tensile test in which a high width : thickness strain ratio is recorded, the "R" value mentioned under tensile testing, should represent a material with good drawability.

* This article is based on two lectures included in a special course on "The Metallurgy of Deep Drawing and Pressing", held at the Department of Metallurgy, Birmingham College of Advanced Technology.

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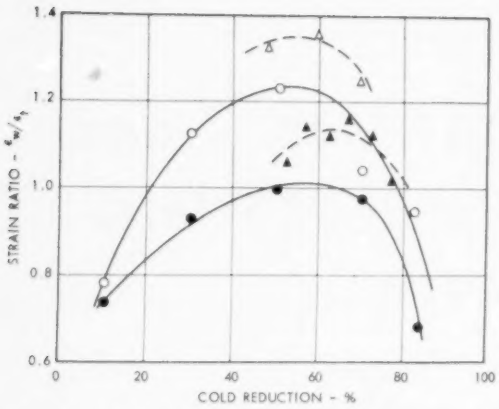


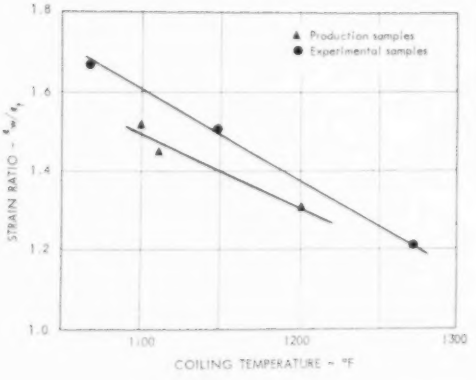
Fig. 26.—The effect of cold reduction prior to annealing on the anisotropy of mild-steel sheet as measured by its average strain ratio. Killed steels: △—production samples, ○—laboratory samples. Rimmed steels: ▲—production samples, ●—laboratory samples. (Whiteley (41))

Whiteley believes the drawability of mild steel stems not only from its good work-hardening capacity but also from its marked anisotropy. The superiority of stabilized steels in deep drawing and stretch-forming is reflected in their higher width : thickness strain ratios, while they have practically the same work-hardening capacity as rimming steels. A recent study[43], of anisotropy in sheet steel showed that the type of anisotropy revealed by the strain ratio was due to preferred orientation in the crystallography of the sheet and not due to mechanical anisotropy caused by inclusions, segregates and grain boundary fibre structures. This is supported by *Whiteley* who summarizes roughly that "cube-on-corner" texture tends to produce the highest strain ratios, the two most common textures in mild steels being (111) [$1\bar{1}0$] and (111) [$11\bar{2}$]. The attainment of these textures in mild steel depends on composition, hot-mill coiling temperature, degree of cold working and annealing treatment. Fig. 26, from Whiteley's work, shows strain ratio to increase to a maximum at 50 to 60 per cent cold work and then decrease for still higher reductions. This is explained by the gradual formation of the favourable (111) [$1\bar{1}0$] texture up to 50/60 per cent cold work followed by the introduction at higher reductions of the less favourable (100) [$1\bar{1}0$]. The superior strain ratios of stabilized steels compared with rimming steels can be attributed to the more intense (111) [$1\bar{1}0$] type of texture which arises from the procedure followed to achieve pancake-shaped grains. This desirable grain shape is promoted by relatively low coiling temperatures while hot coiling tends to produce equiaxed grains. The effect of coiling temperature on the resulting strain is shown in Fig. 27.

Limited experience of correlation of the width : thickness strain ratio, "R", derived from the tensile test, with press performance has so far been encouraging according to *Whiteley*[41]. Evidence of correlation of strain ratio and simulative test results is presented in a later section. *Lankford, Snyder* and *Bauscher*[7], showed that a knowledge of the work-hardening index, "m", of the material together with the strain ratio, "R", could be used for satisfactory correlation with press performance. Their correlation tests showed that an "R_l" value ("R" value on a tensile test-piece cut in the longitudinal direction of the sheet) less than 1.5 and an "m" value below 0.24 gave predominantly poor press performance. Taking either of these values separately does not give a very good measure of press performance but a very high proportion of lifts having both "R_l" values and "m" values above the minima had a good press performance. They concluded that the best measure was the factor ($R_l \times m$). Although there was considerable scatter, they noted that low yield-point : U.T.S. ratios tended to be associated with a high work-hardening index and a high strain ratio.

The arguments outlined above have been concerned with anisotropy of sheet with considerable emphasis on the strength of the material in the thickness direction. For a considerable period it has been recognized that strains in the longitudinal and transverse directions of the plane of sheet often exhibited anisotropy. This is particularly important in severely formed parts where the degree of strain in these two directions may differ considerably. If

Fig. 27.—The effect of the hot-mill coiling temperature on the anistropy of aluminium-killed steel sheet as measured by its average strain ratio. The production sample data are based on twenty-four different coils of steel processed according to different standard practices. The experimental data are based on nine coils of steel from the same heat which were given identical processing except for coiling temperature. (Whiteley(41))

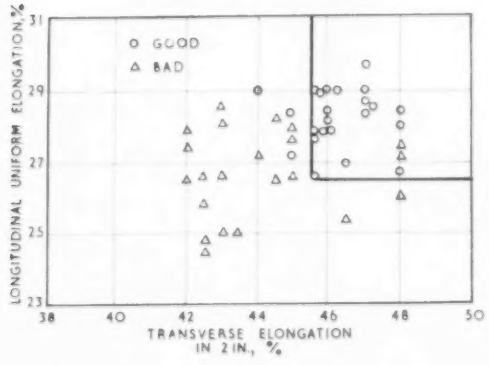


the elongations in the two directions are found by simple tensile testing, advantage can be taken of the directional ductility in ensuring that the most ductile direction in the sheet coincides with the direction of greatest strain in the component. Fig. 28, from work by *Nelson*[3], shows the correlation between combined high elongation in both directions with press performance on a difficult part where localized transverse strain was 35 to 40 per cent while longitudinal strain was 25 to 30 per cent.

Bulge tests, to a large extent, take into account differences in ductility in various directions in the plane of the sheet. On the other hand they also tend to blur some properties which would be easily distinguished in the simple tensile test. Thus Fig. 29 is a comparison of stress/strain curves obtained from a normal tensile and a hydraulic bulge test by *Gough* and *Hankins*[22]. The tensile and bulge test curves correlate well but the yield point, quite apparent on one of the tensile curves, has almost disappeared from the equivalent bulge test curve. This is probably due to the fact that the yield stress varies in different directions in the sheet and yielding will therefore take place over an increasing stress range in the bulge test because, in effect, all directions are being tested at once.

Rubenkova[44], in comparing deep-drawing quality with simple tensile properties and bulge-test properties for a number of steels similar in yield point, microstructure, composition and hardness, showed that for good drawability the U.T.S. was 25.4 to 34.3 tons per sq. in. with a strain at the ultimate stress of 16 to 30 per cent. Poor drawability was exhibited by steels with U.T.S. 21.0 to 25.4 tons per sq. in., with a strain at this point of 9.5 to 16 per cent. When 250 mm. diameter blanks of the same steels were hydraulically bulged, the cup height for similar hydraulic pressures differed considerably as between the good and the poor. A typical example at a pressure of 40.6 tons per sq. in. was a height of 73 mm. for the good steel and 59 mm. for the poor.

Fig. 28.—Correlation between combined high elongations in both longitudinal and transverse sheet directions with press performance. (Nelson[3])



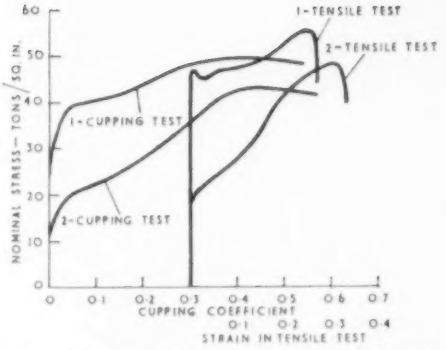


Fig. 29.—Comparison of stress-strain curves obtained on two samples of steel sheet using a hydraulic cupping test and a tensile test. (Gough and Hankins[22])

It is of interest to note that, within wide limits, the effect obtained in a hydraulic bulge test is independent of sheet thickness[45], which is not the case in the small punch cupping tests.

Insufficient work has been done on bulge testing to be able to judge the method critically and a number of authorities have suggested that it is worthy of more detailed investigation. It should not be difficult to scale the test down for routine purposes if the usefulness of the results can be assessed accurately.

Correlation of Simulative Test Results with Industrial Press Results

The Erichsen or Olsen cupping test gives a single figure in assessing sheet quality for presswork but this does not give completely satisfactory correlation with press-shop results[23]. The lack of complete correlation is probably due to the fact that the metal is biaxially stretch-formed in the test with little drawing-in allowed while many press-jobs do involve a certain amount of drawing-in. On the other hand, there is good correlation between the Erichsen value and stretch-forming jobs in the press-shop[4, 26, 46]. There are two disadvantages in the Erichsen/Olsen type of test even when applied to stretch-forming. Some workers claim that the test is limited in judging large press-work by its relatively small size,[2, 4] and by the fact that it may not reproduce the correct frictional conditions. A high degree of friction between the punch and the blank restricts free stretching over the punch face, necking occurs where the punch is just making contact with the metal and this leads to fracture at the point rather more remote from the centre than should occur. The degree of uncertainty over simulation of frictional conditions is probable responsible for most of the difference of opinion of the usefulness of this type of test. If

anything, the Erichsen type of test should be generally well-lubricated, compared with the large pressing, since it is relatively small and the degree of lubrication is under the control of the operator to a larger extent than in the press-shop. This is supported to some extent by work by *Panknin*[45], who showed that there is a relationship between the Erichsen cupping value and hydraulic bulge-test results. Since the Erichsen cupping test results are dependent on sheet thickness the comparison is only valid when sheets of equal thickness are compared. The relationship between the Erichsen value, for constant sheet thickness, and the thinning of the bulge wall at a constant bulge height is linear. Friction plays no part in the hydraulic bulge test and if a close relationship holds between the bulge and Erichsen results then friction cannot be an overwhelming variable in the Erichsen test. This is more likely to be the case if lubrication during the test is efficient.

Recent improvements in the specification for the Erichsen cupping test particularly and the use of automatic testing equipment have helped considerably to improve the correlation between cupping values and stretch-formed parts in industry. The usefulness of the test in assessing grain-size and pronounced directionality is not impaired by its small size or by frictional considerations.

Wilson, *Moreton* and *Butler*[68], considering that the Erichsen/Olsen type of cupping test was small, introduced a disproportionate amount of bending for thick sheets, was capable of allowing an indefinite amount of drawing in of the blank, and varied in lubrication effects, investigated a new stretch-forming test. They used a forming tool consisting of a 2-in. diameter hemispherically ended punch on a variable-speed press deforming a 5-in. square test-piece firmly locked to prevent drawing in of the flange. The die ring was 2.22 in. internal diameter with a $\frac{3}{8}$-in. profile entry radius. The variable speed allowed a wide choice of frictional conditions owing to the effect of speed on the lubrication efficiency, and also allowed investigation of the effect of speed on the material itself. The stretch-formability value was defined as the punch penetration which was just sufficient to produce a clear crack. The stretch-formability value was found to be less affected by variations in sheet thickness than with the Erichsen test and it also appeared to be less sensitive to the bending properties of the material. Discrimination between material taken from the top and bottom sections of rimmed-steel ingots proved to be superior to that obtained in Erichsen tests. Frictional restraint by the punch nose on the sheet is reduced if liquid lubricants are used and punch speed is increased and this allows much larger strains in the polar regions of the bulge. The effects of speed on material can be examined by using a solid lubricant such as graphite which is insensitive to speed. This test is complementary in a useful way to a pure deep-drawing test and in this light is worthy of further attention.

The logical development of the Swift cup-drawing test involved correlation with industrial press results. One batch of results is considered in an appendix to the tentative specification for the Swift test[23]. The results of trials to correlate Swift test results, using both the flat-nosed punch and the hemispherical punch, with a range of press work were not sufficiently detailed to be analyzed statistically. In any case the press results were expressed qualitatively. However, general agreement was obtained between the test results and press results for a variety of jobs and materials. The hemispherically-bottomed cup results showed a rather better correlation than the flat-bottomed cups but both sets of results showed a noticeable proportion of anomalies. It can be said that when appreciable stretch-forming of the sheet occurs over the face of the punch the flat-bottomed cup version of the limiting drawing ratio does not assess the material correctly. On the other hand the flat-bottomed cup test is an acceptable assessment of material for true deep-drawing operations[28].

In a similar manner to the Swift test, the results of the conical cup test have also been correlated with press practice[39]. In this investigation, statistical significance tests were applied to the results. The conical cup test with a round-nosed punch was effective in evaluating the formability of steel sheet for a difficult tank shell, whereas the formability could not be predicted significantly from longitudinal elongation, transverse elongation, hardness or Erichsen values. The same test was not very effective in predicting press performance in forming fenders for small cars but it was statistically better than the elongation, hardness and Erichsen values. Similar tests were conducted for the roof panels of a small car and perfect correlation was obtained although only seven sets of results were available. In this case the elongation and Erichsen results were also reasonably successful in predicting press performance though not absolutely perfect. The correlation of conical cupping test values using the round-nosed punch are not perfect but they are sufficiently encouraging to warrant further study for cases where the test introduces much the same ratio of drawing to stretching as does the industrial component. The test is simple to operate, needs no expensive equipment assuming a means of driving the punch is available, and does not require large areas of sheet for test purposes.

Correlation of Simulative and Non-simulative Test Results

It is very much easier to compare the results of various simulative tests with each other and with

TABLE V

Sheet No.	Erichsen cupping value mm.	Elong. per cent on 2 in. G.L.	Uniform elong. per cent
A1	7.2	8.0	5.1
2	7.4	6.8	4.1
3	7.6	6.8	4.4
B1	7.6	10.5	7.2
2	7.4	10.0	7.1
3	7.6	12.0	7.7
C1	7.6	17.5	11.6
2	7.6	17.2	11.7
3	7.6	16.0	10.3

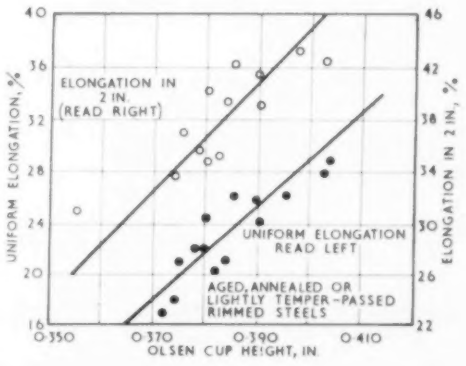
various non-simulative test results than to compare either type with commercial press results. Provided firm correlation is established between one set of test results and press performance for a particular type of pressing, it is relatively simple to judge how another set of results will predict performance by comparing the two sets of test results together. Information gained in this way is not as valuable as direct correlation with press results but is nevertheless very useful.

Considering cupping tests first, Erichsen and Olsen values correlate well with uniform elongations, or elongation at maximum load in the tensile test, for most materials. The elongation values and the cupping-test values are both valuable in assessing stretch-forming performance. Uniform elongations of typical rimming steels are fairly closely related to cupping values (*see* Fig. 30), but killed steels do not correlate quite so well. The Table V([47]), records the average of four Erichsen cupping values on nine separate sheets of Al-3½ per cent Mg. alloy in the ¼-hard condition, together with the total elongation and uniform elongation results for each sheet. It is apparent that in this case the Erichsen cupping value does not correlate very well with the elongation figures.

In comparing cup-drawing test results with Erichsen cupping values and simple tensile test results (the width : thickness strain ratio was not measured) *Beisswanger*([46]), found that the Erichsen and tensile test results did not enable the material to be rated for deep drawing accurately, although they did allow selection for stretch-forming operations. On the other hand, he found that the limiting drawing ratio from the cup-drawing test provided an index of the drawability of sheets in different deep-drawing processes and also determined the tendency to form stretcher-strains, wrinkles and cracks. *Swift*([25, 28]), showed that no correlation existed between limiting drawing ratio in a cup-drawing test and the Erichsen cupping value. However, when oversize blanks were used in the cup-drawing test, then the order of merit based on the depth of draw to fracture did agree approximately with the order obtained from the Erichsen cupping test. He further pointed out that the general elongation for a metal in a tensile test is a measure of its ability to survive plastic strain of a simple type and can be defined in terms of its basic work hardening characteristics over a limited range. In deep drawing, the stress system is not simple and there is no reason why the general elongation under simple tension should provide a reliable criterion of drawability. No satisfactory correlation exists between this general elongation and limiting drawing ratio determined with either flat or round ended punches. Although the form of the strain-hardening characteristics for a metal must in some way determine its drawing properties, and does determine its general elongation, it is an oversimplification to presume a relationship between the two. There are exceptions to the opinion of Swift as is illustrated by *Pearce*([48]), who compared Swift cup-forming test results, using both flat-ended and round-ended punches, with 2-in., 8-in., and uniform elongation figures, proof-stress (0.1 per cent)/U.T.S. ratio, for aluminium alloys containing from 0.5 to 7.5 per cent magnesium, in soft, ¼-hard and ½-hard conditions. The round-bottom cup results correlated well with the tensile-test results. The highest limiting drawing ratio was associated with the alloys having low proof stress, low proof-stress/U.T.S. ratio, high 2-in. and uniform elongations. These conditions were given by all the alloys in their soft condition rather than temper rolled. The flat-bottomed cup tests did not correlate well with the tensile results. High elongation figures are not essential since no great stretching occurs and the only degree of correlation appeared to be that a material with a proof stress of less than about 7 tons per sq. in., appears to be too weak and an extremely low elongation indicates inability to form the radius of the cup properly.

A further set of results on ¼-hard Al-3½ per cent Mg. sheets, the same sheets which gave the results

Fig. 30.— Correlation between uniform elongation, elongation on 2 inches, and Olsen cup height for rimmed steel



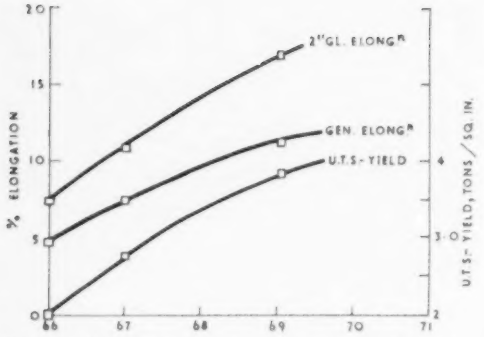
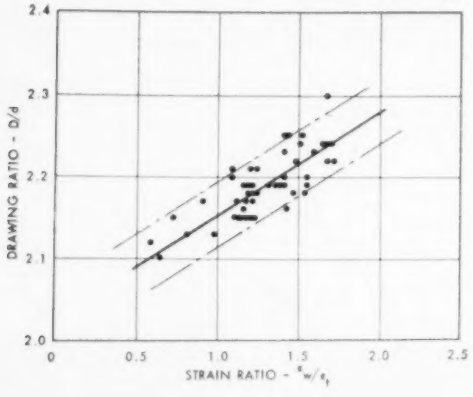


Fig. 31.—Correlation of mechanical properties with Erichsen cup-drawing test critical blank diameter for ½-hard, 3½ per cent Mg. aluminium sheet

quoted in the last table above, is shown in Fig. 31[47]. All the results of sheets from the same batch, A, BorC, were averaged and the 2-in. elongation, general elongation and the difference between U.T.S. and yield-point figures for the three batches all correlate well with the critical blank diameter as judged by the Erichsen cup-drawing test. Contrary to Swift's general statement there are therefore cases where cup-drawing test results do correlate with mechanical properties. It should be noted however that this evidence is restricted to one series of aluminium alloys which exhibits unusual plastic strain characteristics.

When discussing correlation between tensile test results and cup-drawing test results, *Swift*[25, 28], *Pearce*[48], and the present author, used the simple tensile-test results and did not consider work-hardening index and width : thickness strain ratios. *Whiteley*[41], after testing a variety of mild steels, stainless steels and aluminium alloys concluded that

Fig. 32.—The relationship between the maximum cup-drawing ratio measured in the Swift test and the anisotropy of the metal as measured by its average strain ratio (Whiteley[41])



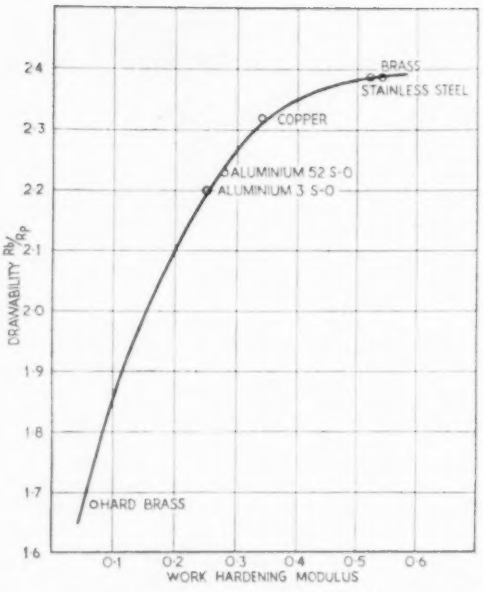


Fig. 33.—Relationship between critical drawing ratio and work-hardening index for a variety of sheet materials. (Arbel[8])

the width to thickness strain ratio correlated with the Swift cup limiting drawing ratio. Fig. 32, shows the degree of correlation achieved. *Arbel*[8], plotted true stress/true strain curves on a $\log_e$-log basis for several materials and calculated the work-hardening index from the gradient of the line. He then showed that the drawability of each material as measured by the limiting drawing ratio in a flat-bottomed cup-drawing test was related to the work-hardening index, giving the curve shown in Fig. 33. It would be of considerable interest to extend the full analysis of tensile-test results to a wider range of materials than attempted so far, and compare the work-hardening and strain-ratio results with pure deep-drawing test results, and general-elongation and work-hardening results with pure stretch-forming test results.

An entirely different approach to the problem of correlating tensile-test results with cup-drawing test results has been made by *Crane*[49], *Sachs*[50], *Von Zeerleder*[51], and *Ludington*[52]. All of these workers have attempted to relate maximum possible cup strengths or drawing loads to the U.T.S. of the material. Crane derived the expression, P = Sπd.t., where S = U.T.S., d = cup diameter, and t = metal thickness. Sachs assumed metal thickness to be small and punch diameter large in relation to it, and developed the expression F = 1.1.Sπd.t. where "F" is the maximum value for cup strength and equivalent to punch load at fracture. Von Zeerleder

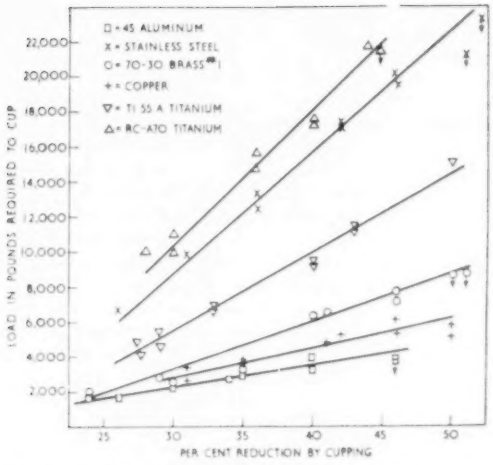
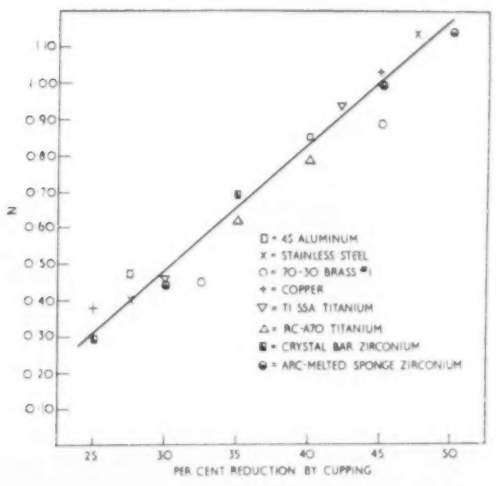


Fig. 34.—Effect of per cent reduction by cupping on punch load. (Ludington[69])

states that, for aluminium, the drawing load can be computed from F = S.d.t.n., where "n" is a factor dependent on the drawing ratio. Ludington plotted punch load against percentage reduction by cupping for a variety of materials and each material gave a linear relationship (*see* Fig. 34). He then plotted cupping stress/U.T.S., designated "N" (where N = L/AS, "L" being the punch load, "A" the cross-sectional area of the cup wall and "S" the U.T.S.) against percentage reduction by

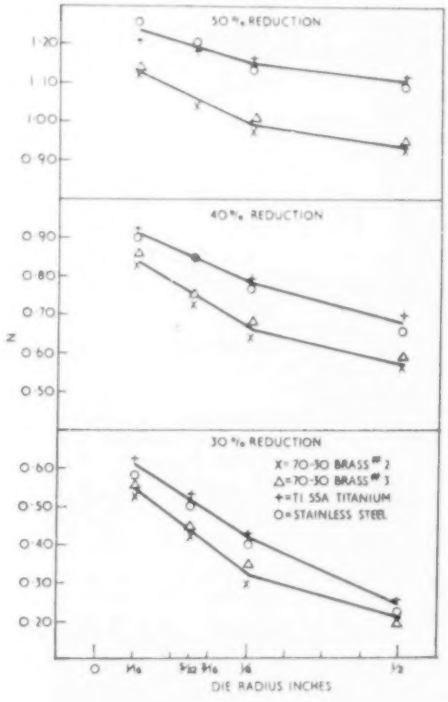
Fig. 35.—Effect of changing cupping loads of Fig. 34 into cupping stress and dividing by U.T.S., to obtain "N", and relating this to per cent reduction by cupping. (Ludington[69])



cupping, to give a linear relationship largely independent of material, as shown in Fig. 35. In plotting Fig. 35, Ludington used values of punch load taken from the average lines in Fig. 34. In doing this, he eliminates the effect of a certain degree of scatter in the results of Fig. 34 before they are transferred to Fig. 35 but, in spite of this, some further scatter appears. This would have been further exaggerated had the first rationalization not been made. In demonstrating an empirical relationship, Ludington is probably justified in making these corrections, but it should be pointed out that in using such a relationship as a basis for a test procedure, the results are unlikely to be as accurate as Ludington's, unless a large number of samples are considered. In Fig. 35, results of some independent work are also included and fall in reasonably well with Ludington's own results. The linear relationship of "N" with percentage reduction indicates that L = π t.s.(d-t) N where d = die diameter.

Ludington then investigated the effect of varying the die-entry radius on "N" for various materials. The die-entry radii were in the range $\frac{1}{16}$ to $\frac{1}{2}$ in., the die diameter being 1.500 and punch 1.400 in. since the sheet thicknesses were in the range

Fig. 36.—Effect of die-entry profile radius on "N" values. (Ludington[69])



0.034 to 0.041 in. no ironing took place in the radial gap of 0.050 in. The highest loads, and hence the highest "N" values, occurred with the smallest die entry radius, as shown in Fig. 36. This figure also shows that the curves for brass lie substantially below the curves for a titanium alloy and stainless steel, and the difference between the curves increases as the percentage reduction increases.

Ludington points out that the maximum value of "N" is usually greater than 1.0, which means that the maximum stress in the wall of the cup is usually higher than the normal U.T.S. of the material. He attributes this to the difference in stress systems between cup forming and normal tensile testing and supports this by the fact that a tensile test-piece constrained from contracting when tested shows an apparent tensile strength 15 per cent higher than normal. Throughout his work Ludington used the original sheet thickness in calculating stresses in the cup walls. Admittedly there was no ironing and it is possible even that the walls had thickened up, but an "N" value greater than 1.0 could also arise through the load bearing parts of the cup having an average thickness less than the original sheet thickness. Furthermore, Ludington lists average U.T.S. figures without clarifying whether he has accounted for anisotropy. Generally speaking, the U.T.S. in the weakest direction would appear to be the best for calculating "N". If a higher U.T.S. was used this would have the effect of giving "N" a maximum value in excess of 1.0.

Ludington concludes that if an "N" value of 1.10 is taken as a practical maximum, there exists a criterion for judging the maximum percentage reduction by cupping, independent of material, provided the U.T.S. is known. Also, using curves of "N" versus percentage reduction by cupping, it is possible to calculate cupping loads for many quite different materials easily and with reasonable accuracy. In the present author's opinion, calculation of the cupping load for simple press-shop operations does not require great accuracy and Ludington's method is probably satisfactory for most purposes. On the other hand, if the maximum reduction is required for test purposes it would appear there are too many sources of error to allow an accurate estimate to be made, even if the calibration curves themselves were absolutely free from error. This is due to the fact that the relationship between "N" and percentage cupping reduction is not entirely independent of material and there is uncertainty over the correct value by which to represent the ultimate tensile strength. Nevertheless, this type of relationship is of considerable interest and is worthy of further study.

Finally, *Yoshida*[52], has compared results of Swift cup-drawing tests, conical cupping tests,

TABLE VI—*Test values by various formability testings* (sheet metal thickness : 1.0 mm.)

Materials / Testing	L.D.R.† (1) F.P.*	L.D.R.† (2) R.P.**	C.C.V.†† (mm.) (3) F.P.*	C.C.V.†† (mm.) (4) R.P.**	(5) Erichsen value (mm.)	(6)††† Bore expansion ratio $(R_i/r_i)_{\beta}$
R-1 (killed steel)	2.25	2.42	44.57	44.94	11.5	3.45
R-2 (rimmed steel)	2.12	2.27	45.38	46.24	10.3	2.98
R-3 (,,)	2.11	2.23	45.34	46.33	10.2	2.98
R-4 (,,)	2.19	2.22	45.86	46.61	10.0	2.78
R-5 (,,)	2.09	2.19	45.73	46.19	10.5	2.83
R-6 (,,)	2.15	2.19	45.53	46.70	—	—
R-7 (,,)	2.07	2.16	45.55	46.43	11.3	3.01
R-8 (copper)	2.22	2.26	45.58	45.61	11.9	2.42
R-9 (aluminium)	2.10	2.12	57.02	47.28	10.8	2.04

Rank correlation coefficient

$r_{12} = 0.70$ $r_{15} = 0.19$ $r_{16} = 0.02$ $r_{23} = 0.65$
$r_{34} = 0.70$ $r_{25} = 0.14$ $r_{26} = 0.31$
$r_{13} = 0.32$ $r_{35} = 0.17$ $r_{36} = 0.86$
$r_{24} = 0.80$ $r_{45} = 0.52$ $r_{46} = 0.41$
$r_{56} = 0.08$

Rank correlation coefficient with mild steel alone

$(r_{12}) = 0.83$ $(r_{15}) = 0.09$ $(r_{16}) = 0.03$ $(r_{23}) = 0.77$
$(r_{34}) = 0.60$ $(r_{25}) = 0.09$ $(r_{26}) = 0.31$
$(r_{13}) = 0.31$ $(r_{35}) = 0.49$ $(r_{36}) = 0.83$
$(r_{24}) = 0.54$ $(r_{45}) = 0.66$ $(r_{46}) = 0.43$
$(r_{56}) = 0.77$

† Swift Cup-Forming Test.
†† Fukui's Conical Cup Test.
††† Hole expanding test with conical die and round-bottomed punch.
†††† r_{12} *etc.*: Rank correlation coefficient between (1) and (2) *etc.*
* Test values with flat-bottomed punch.
** Test values with round-bottomed punch.

Erichsen cupping tests and hole-expanding tests for a selection of steels and copper and aluminium. The results are shown in Table VI, together with correlation coefficients for each column of results compared with the others.

Considering the correlation coefficients for the steels only, it is interesting to note that the two sets of Swift test results, using the two types of punch, correlate better ($r_{1\cdot2} = 0.83$) than the conical cupping test results with the two types of punch ($r_{3\cdot4} = 0.60$). Comparing the Swift test with the conical cupping test when both use flat-ended punches the correlation is not very good ($r_{1\cdot3} = 0.31$) but when both use round-ended punches the correlation is a little better, though still not good ($r_{2\cdot4} = 0.54$). If the Swift test with a round-ended punch is compared with the flat punch version of the conical cup test, the correlation is reasonably good. This rather suggests that the conical cupping test using a round-ended punch, involves a greater element of stretch-forming than the Swift test using a round-ended punch, and when a flat-ended punch is used in the conical cup test, the stretch-forming component is reduced to something more akin to that operating in the Swift round-ended punch test. This argument is supported by the fact that the Erichsen cupping values, recognized as very largely stretch-formability dependent, correlate much better with both of the conical cupping tests than with either set of Swift test results. At least there is very little doubt that the conical cupping test using the round-ended punch, combines stretch-forming with deep drawing, with the emphasis on stretch-forming. It might be a useful rating test, therefore, for operations which are mainly stretch-forming but do involve a lesser degree of deep drawing. Unfortunately, it would appear that the ratio of the two forms of deformation to each other is fixed and also nearer to stretch-forming, which is already fairly well catered for with the Erichsen and similar cupping tests.

The Effect of Strain-ageing on Test Results

The main interest in the influence of strain-ageing in press work is in the use of rimmed mild steel, particularly in the motor industry. A major cause of splitting, and the production of imperfect pressings, is the use of rimming steel which has been allowed to age, for their manufacture[53]. Annealed rimmed steel strain-ages to varying degrees after cold work, resulting in reduced ductility and raising the hardness and yield point. The cold work required to straighten annealed coils is sufficient to induce some ageing even in dead-soft rimming steel. The extent to which ageing takes place depends on a number of variables, such as grain-size, nitrogen content, degree of temper rolling and temperature of rolling and storage after rolling.

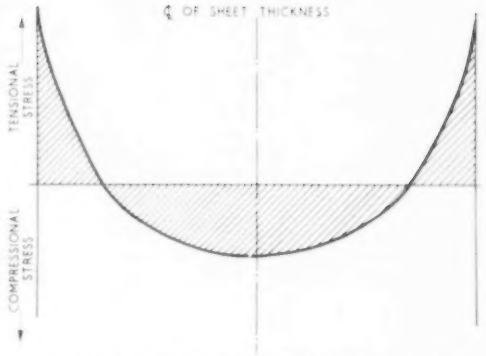


Fig. 37.—Schematic representation of the determination of strain-ageing using index intermediate artificial ageing

Ageing in rimmed steel is first detected as a kink just above the elastic region of the stress-strain curve. This develops into a pronounced yield point on the curve which rises progressively with time as much as 4 to 5 tons per sq. in. for fully-aged material. The poorer pressing qualities of aged, compared with freshly temper-rolled, rimmed steel are reflected most clearly by progressive examination of the yield stress with time. The yield-point elongation is also a close measure of the severity of stretcher strains to be expected in pressing. Tensile tests after increasing times at room temperature will follow the progress of the yield point and to a large extent the pressing quality of the material can be assessed from the results but a single test at room temperature will not predict the change in properties to be expected some weeks hence. Methods have been developed, therefore, to assess the long term ageing characteristics of a steel in a short time. One test consists of straining a tensile test-piece through the yield point to 10 per cent elongation on a 2-in. gauge length. The load is noted at this point, the test-piece is unloaded, removed and artificially aged for 4 hours at 100° C. The test-piece is then reloaded and the new yield point is measured. The difference in stress between the new yield point and the load recorded before artificial ageing expressed as a percentage of that load is taken as the ageing index. The method is shown schematically in Fig. 37. *Knight*[54], lists the following typical ranges for the ageing index; open-hearth rimmed steel, 10 to 14 per cent; basic Bessemer (high nitrogen) steel, 14 to 18 per cent; open-hearth aluminium-killed steel, 0 to 5 per cent; open-hearth vanadium-killed steel, 8 to 11 per cent.

If duplicate test-pieces are taken then measuring the ageing characteristics is a simple matter of testing one in the as-received state and the other after artificial ageing for 4 hours at 100° C.

Strain-ageing is accelerated by raising the temperature and, by a suitable choice of temperature

TABLE VII

Time at 15° C	Time at 21° C	Time at 30° C	Time at 100° C	Time at 120° C	Time at 150° C
12 months	6 months	6 weeks	4 hours	1 hour	10 min.
6 months	3 months	3 weeks	2 hours	30 min.	5 min.
3 months	6 weeks	10 days	1 hour	15 min.	2½ min.
1 month	2 weeks	3½ days	20 min.	5 min.	—
1 week	4 days	1 day	5 min.	—	—
3 days	36 hours	9 hours	2 min.	—	—

and time, a steel specimen can be aged in a short time to the equivalent condition achieved at room temperature in months. It can be shown that[55],

$$\log_{10}\frac{t_r}{t} = 4400\left(\frac{1}{T_r} - \frac{1}{T}\right) - \log_{10}\frac{T}{T_r}$$

where t_r is strain-ageing time at room temperature, $T_r(K^\circ)$, and t is strain-ageing time at an elevated temperature $T(K^\circ)$. This expression is derived theoretically from the rates of diffusion of carbon and/or nitrogen in mild steel assuming the return of the yield point is dependent on the locking of dislocation atmospheres according to the Cottrell-Bilby theory[56]. The theoretical relationship has received considerable support from experimental comparisons of room temperature and elevated temperature ageing effects up to as much as 200° C. The properties used to reflect the strain-ageing effect have been: limit of proportionality[55]; yield-point elongation[55, 57]; ductility[55]; U.T.S.[55, 58]; hardness[59, 60]; impact toughness[61]; and electrical resistivity[62].

Table VII derived from figures given by *Hundy*[63] compares times for equivalent degrees of ageing for various temperatures.

Considerable acceleration of strain-ageing due to exposure of sheet in direct sunlight or similar conditions representing a temperature of 30° C. or more is evident compared with winter storage conditions at 15° C. From the table, accelerated strain-ageing for up to 4 hours at 100° C. appears to be suitable for assessing strain-ageing potentiality. A lower temperature unnecessarily prolongs the test and a higher temperature is open to the objection that a small error in timing becomes important. A higher temperature also introduces the possibility of stress relief in the specimen which is not matched by exactly similar stress relief over the longer period at room temperature. Since the yield-point elongation can be masked by internal stress, changes in internal stress will produce corresponding changes in the yield-point elongation.

Hundy's explanation[63], of the masking of the yield point by internal stress is that a mild-steel sheet which has been temper-rolled will have an internal stress distribution similar to that shown in Fig. 38. When such a sheet is stretched, the actual load acting on a particular grain is the algebraic sum of the external load plus the internal stress at this point, taking the sign into account. The external grains are acted upon by the highest tensile stress and one of these will probably yield first. The external load will have to be raised, however, to persuade the next layer of grains to yield and any tendency to sudden overall yielding will be resisted by the still elastic core. Thus steel sheet containing high residual stresses would show a rounded stress-strain curve rather than one with a sharp yield point and would not give stretcher-strains on pressing. The yield-point elongation is in fact removed by an extension of 1 per cent obtained by cold-rolling whereas yield-point elongation can only be removed by pure tensional strain (which would not give the same internal stress distribution as temper-rolling) when the strain exceeds the yield-point elongation, a matter of 4 per cent or more[64]. A yield-point elongation of up to about 1½ per cent can be removed by roller levelling in the press-shop immediately prior to pressing and this prevents stretcher-strains if strain-ageing had not already proceeded too far. Roller levelling is less effective than temper-rolling in producing an effective residual stress system and if applied after temper-rolling may even decrease the total resistance to stretcher-strain production[63].

Fig. 38.—Stress distribution across the thickness of a temper-rolled sheet

Strain-ageing takes place normally in temper-rolled sheet with the usual increase in hardness, U.T.S., and fall in ductility, but the yield-point elongation, and hence the formation of stretcher-strains, may continue to be masked by the residual stress system of the sheet.

In another account, *Hundy*[65] shows that in the normal temper-rolling range, it is probable that fastest stretcher-strain-ageing will occur in the transverse direction because the residual stress system is less effective in this direction. This suggests that testing of steel sheets for freedom from stretcher-strains should be carried out either in both directions or in the transverse direction only. Testing in the rolling direction only, might lead to an optimistic prediction of the behaviour of the sheet on pressing.

Attempts to follow strain-ageing with simulative tests have not been very successful. *Swift*[24], showed that if a hemispherical-ended punch was used in the cup-drawing test, it was sensitive to yield point. However, *Pearce*[53], has shown that a rise in the yield point of 3 to 4 tons per sq. in. in a number of heats of rimmed steel is not reflected in a decreased limiting drawing ratio for either the Swift flat- or hemispherical-ended punches. In fact, in some cases the limiting drawing ratio increased after ageing. Since Pearce used artificial ageing at 100° C., it is possible that some stress relief effect might account for the better drawability in some cases, in spite of the ageing. Pearce then proceeded to show that a hemiellipsoidal-ended punch, with a major : minor axis ratio of 3 : 2, does differentiate between aged and non-aged steel to a larger extent than flat or hemispherical-ended punches. Whereas, with the hemispherical-ended punch, even after reducing blankholder pressure to a minimum, a difference of one increment only in the limiting drawing ratio was recorded between fresh and fully aged sheet, the hemiellipsoidal punch differentiated by three increments. The limiting drawing ratios with the hemiellipsoidal punch correlated reasonably well with the respective Olsen values, Fig. 39, and from this Pearce infers that the hemiellipsoidal punch is unlikely to rate the material in terms of deep-drawability. Of the three punches tried only the hemiellipsoidal one gives sufficient evidence of the extent of change in yield point and this is attributed to the greatly increased stretch-forming component as a proportion of the total deformation.

Ullman and *Thomas* carried this type of investigation a stage further[66], by trying a flat-nosed punch, a hemispherical-nosed punch and four hemi-ellipsoidal-nosed punches with major : minor axes of $1\frac{1}{8}$: 1, $1\frac{1}{4}$: 1, $1\frac{1}{2}$: 1 and 2 : 1. Although they found that limiting drawing ratio results with the $1\frac{1}{2}$: 1 hemiellipsoidal-nosed punch showed a trend with ageing time, they were not convinced that this was a significant trend. They support the opinion that

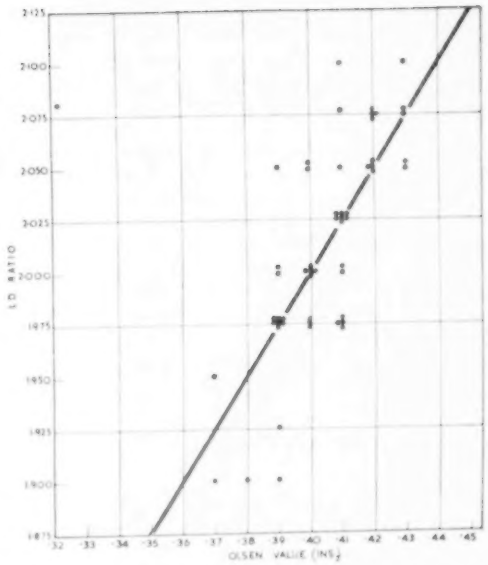


Fig. 39.—Limiting drawing ratio using a hemi-ellipsoidal punch related to Olsen value for rimmed-steel sheet. (Pearce[53])

the flat-nosed punch offers no possibility of correlating press-shop results for temper-rolled rimmed steel with standard Swift test results.

Thus, it appears that simulative tests, in their present state of development, are somewhat insensitive to the loss of ductility associated with strain-ageing of temper-rolled rimmed steel. For the present, it is advisable to rely on the results of the simple tensile test together with artificial ageing techniques.

Conclusion

If the whole field of testing of sheet metal for deep-drawing and stretch-forming operations is considered it is apparent that considerable progress has been made in some aspects but little in others. It is not difficult to rate materials in terms of pure stretch-forming. The uniform elongation found from a simple tensile test, the extent of the plastic range in terms of stress, and the work-hardening index, are all appropriate measures of important parts of the mechanism of stretch-forming. One tensile test is satisfactory for isotropic materials but tensile tests in at least longitudinal and transverse directions are more appropriate for most sheet materials. Biaxial testing is an appropriate means of combining properties in all directions. The hydrostatic bulge test which produces stretch-forming in the absence of external friction is a fundamental test rather than a simulative test and warrants further examination. The stretch-forming

tests involving friction are useful as routine simulative tests but most of them could be improved. Most of them produce large strains locally over a small area and superimpose appreciable bending at the rim of the bulge as a result of the limited size, particularly when thick sheets are tested. When pure stretch-forming is to be assessed. there are good grounds for preventing the flange from being drawn in. The test procedure outlined by *Wilson*, *Moreton* and *Butler*[68], attempts to overcome several of the objections to the smaller cupping tests. It deserves further attention as a routine test although probably offering less promise than the hydraulic bulging test for more fundamental work.

At the other extreme, it is not difficult to assess a material in terms of pure deep-drawability. It is in this field that developments in the interpretation of the tensile test have recently been of considerable interest. The correlation of the width : thickness strain ratio with limiting drawing ratio for steel has been established. It remains to be seen whether this correlation can be extended to other materials. The flat-bottomed cup-drawing tests due to Swift and to Erichsen simulate pure deep-drawing conditions well. The main difference between the two tests in this respect is that the Erichsen version introduces a slight degree of ironing whereas the Swift test does not.

The major difficulty occurs when attempts are made to assess pressing characteristics which combine a rather indefinite mixture of stretch-forming and deep drawing. This covers a vast proportion of general press-work. No single property derived from tensile tests can be used to rate such work accurately even when the ratio of stretch-forming to deep-drawing is known approximately. However, a fully analyzed tensile test can furnish considerable information in revealing those properties which have been correlated separately with the stretch-forming or the deep-drawing aspects.

When simulative tests are used to assess pressing operations which combine more than one basic mode of deformation, they are generally less successful than when simulation is attempted with simple modes of deformation. An exception to this arises when, almost by chance, the test which combines, say, two modes of deformation, does so in the precise ratio which is also present in a particular commercial pressing. Then, the correlation may be very good but it may be nothing like as good with pressings which combine the same two modes of deformation in slightly different ratios. What is required, is a test which can combine two or more modes of deformation in variable but known proportions. Taking the Swift cup-drawing test as an example, the punch-nose profile can be varied from flat to acutely ellipsoidal to increase gradually the stretch-forming component. The performance of a material whether tested with a flat-ended punch or a hemiellipsoidal punch is still rated in terms of the limiting drawing ratio. The test therefore remains essentially a deep-drawing test with increased emphasis thrown on the ability of the stretch-formed zone to transmit the drawing load in the case of the hemiellipsoidally ended punch. Thus the Swift test, even with hemiellipsoidal punches, cannot be regarded as absolutely suited to rating material for operations where the critical factor is stretch-forming rather than deep drawing. Punch profile and die entry radii can be decreased to introduce greater degrees of bending. The Japanese conical cupping test also combines deep drawability with stretch-forming but it does not appear easy to vary the degree of each mode which is introduced into the test. A typical hole-expanding test subjects the blank to shrink flanging beneath the die face, stretch flanging over the punch head and a degree of bending and unbending. Very little can be done to alter the bending characteristics but shrink flanging can be increased by increasing blank diameter and stretch flanging can be increased by increasing the hole diameter. Although it might be possible to produce controlled variation of two major modes of deformation in a simulative test this has not yet been achieved with complete satisfaction. It seems very unlikely indeed that controlled variation of all the modes of deformation involved in general presswork can ever be achieved in a single simulative test. The best approach appears to be to analyze a given pressing in terms of its various modes of deformation and rate then according to their relative importance. Two, or possibly three, simulative tests should be selected so that each test mainly assess the material in terms of one of the major modes of deformation. Of all the tests considered in this review, a fully analyzed tensile test appears to be the most versatile in assessing the ability of material to undergo successfully, pressing by a variety of modes of deformation. It is also the only test at present which reflects strain-ageing processes adequately.

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(*Continued in page* 833)

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The mechanized line (Fig. 1) consists of a guillotine shear, rolls with a lift roller, and four heavy presses; they are a double action, 750-ton press, two single-action, 500-ton presses, and one single-action, 400-ton press.

The line is serviced by bridge cranes of up to 30 tons capacity, a truck tractor and trucks with specially designed containers. All the equipment of the line is provided with very simple ancillary fittings, necessary for the stacking of bundles of sheets (tables, stands), for short distance transport of the sheared sheets, and for the delivery of the components from press to press.

The technical manufacturing process for the doors starts with the operation of cutting a sheet with the shear to the dimensions laid down by the metal layout card. On the front side the shear is equipped with a table of welded construction, on which the bundle of sheets to be sheared is placed. On the guides, by means of which the front end stop of the shear is adjusted, are placed rotating, wooden rollers on cantilever arms, which protect the surface of the metal from mechanical damage, such as scratching. On the exit side of the shear is located a rail track, along which runs a car, set in motion by the bridge crane. By means of the car the sheared sheets are withdrawn from the dead zone of the shear, in order to make it possible to grip the pile of sheets and transport them by means of the bridge crane.

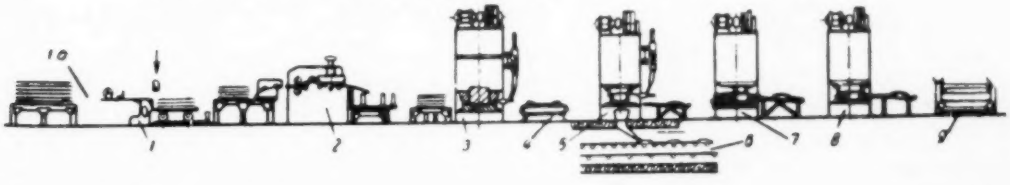
The sheared sheets are then levelled. On the front and back side of the roller levelling stand there are welded tables, onto the first of which is placed the pile of sheets to be levelled. To the table is fastened a mobile platform with a curvilinear surface with guide plates at each side which can be set to width. The purpose of these mechanisms is to create maximum ease of operation and constancy of the location of the sheets to be levelled in the working zone of the rollers.

On the second table is placed a sheet piler, which is a welded structure, consisting of four channel sections, two transverse ones and two longitudinal ones intersecting them. At the ends of the channel sections are fixed vertical guide pillars, which can be adjusted in the horizontal plane. This adjustment makes it possible to adapt the sheet piler to sheets of any desired dimensions, within the limits of 900 to 1,400 mm. in width and 1,300 to 1,600 mm. in length.

Levelled sheets taken from the sheet piler are placed onto a transport grid. In order to prevent the sheets from slipping off the grid during transport by the bridge crane, along its edges are placed stops which can be rapidly raised and lowered (Fig. 2).

After levelling, the next operation is drawing. Before the start of drawing the transport grid with the sheets is deposited in front of the press. The drawing press and the single-action press, on which the shearing operation to trim the outline of the component is carried out, are equipped with " mechanical hands," which ensure the removal of the component from the die without the use of manual labour.

Fig. 1.—Diagram of the mechanized stamping line for external door panels. (1) shear, (2) levelling roll stand, (3) double-action 750-ton drawing press, (4) interstage transporter, (5) single-action 400-ton blanking press, (6) scrap conveyor, (7) single-action 500-ton press, (8) single-action 500-ton press, (9) container, (10) front stop



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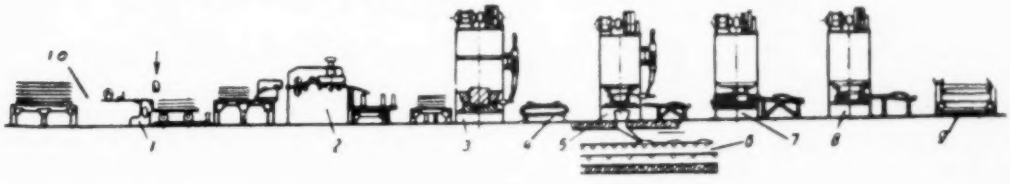
On the second table is placed a sheet piler, which is a welded structure, consisting of four channel sections, two transverse ones and two longitudinal ones intersecting them. At the ends of the channel sections are fixed vertical guide pillars, which can be adjusted in the horizontal plane. This adjustment makes it possible to adapt the sheet piler to sheets of any desired dimensions, within the limits of 900 to 1,400 mm. in width and 1,300 to 1,600 mm. in length.

Levelled sheets taken from the sheet piler are placed onto a transport grid. In order to prevent the sheets from slipping off the grid during transport by the bridge crane, along its edges are placed stops which can be rapidly raised and lowered (Fig. 2).

After levelling, the next operation is drawing. Before the start of drawing the transport grid with the sheets is deposited in front of the press. The drawing press and the single-action press, on which the shearing operation to trim the outline of the component is carried out, are equipped with "mechanical hands," which ensure the removal of the component from the die without the use of manual labour.

Fig. 1.—Diagram of the mechanized stamping line for external door panels. (1) *shear*, (2) *levelling roll stand*, (3) *double-action* 750-*ton drawing press*, (4) *interstage transporter*, (5) *single-action* 400-*ton blanking press*, (6) *scrap conveyor*, (7) *single-action* 500-*ton press*, (8) *single-action* 500-*ton press*, (9) *container*, (10) *front stop*



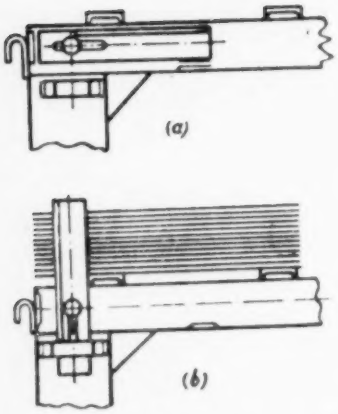
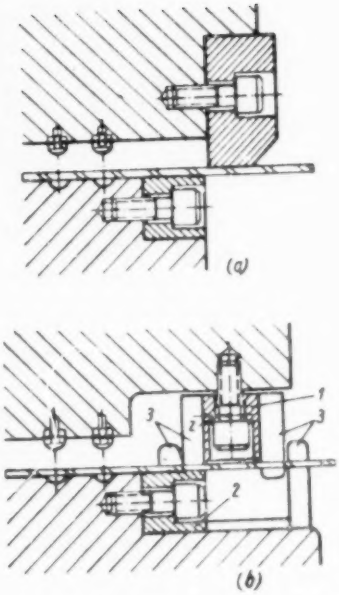


Fig. 2 (left).—Limiting stops of the transport grid: (a) stops in the horizontal position, (b) stop in the vertical working position

Fig. 3 (right).—Blanking shear. (a) Unsuccessful design for blanking shears, (b) design of "floating shears"



On the drawing die are mounted shearing blades, which make it possible to impart the required outline to the sheet before drawing. Earlier a separate press was installed for this operation, for which four men were occupied in working one single-action, 215-ton press. Prolonged experimental work to combine this operation with the drawing operation has led to the development of a design of so-called "floating shears," which have proved satisfactory in operation.

All the preceding designs with a fixed link between the shears and the moving parts of the die did not achieve constancy of the gap between the cutting edges of the cutting sections, since during the setting of the degree of press force applied to the component the pressure ring is considerably distorted in relation to the die of the press (Fig. 3(*a*)).

In the design of the " floating shears" (Fig. 3(*b*)), the top blade, 1, is fastened to the pressure ring of the die, and has two degrees of play as a result of the gaps between the fastening bolts and the apertures in the body of the blade. The lower, fixed blade, 2, and the upper, " floating " blade, 1, are equipped with guides, 3, which ensure constancy of the location of one blade relative to the other, and consequently constancy of the gap.

The following operation is carried out on the 400-ton, single-action press. On the blanking die placed in this press, the cutting profile has been changed, in order to be able to grasp the sheared component with a " mechanical hand." On the back side of the press, the sheared components have a gap 100 mm. wide with an outlet to the outside edge. In this way, part of the scrap is left on the component after the blanking operation; this is grasped by the grips of the " mechanical hand," to withdraw the component from the press. During the flanging operation the " ear " is sheared off by specially installed cutting sections.

The following operation is that of cutting out the window opening on a single-action, 500-ton press. In this operation, for the removal of the component from the press a pneumatic ejector is used, which is operated by an automatic, pneumatic change-over switch (Fig. 4). The ejector is mounted in the die and is an integral part of the whole construction. It is operated by the pneumatic lift mechanism, which is intended to raise the component in the die by 75 mm. Before the lift mechanism reaches the upper limiting position the levers, three for transmission and four for operation, are brought into action; they are fastened by a ball joint to the lift mechanism and also to the bottom plate of the die. The further combined movement of the lift mechanism and of the levers of the ejector makes the already raised component move along the axis of the press and pass completely out of the working zone of the die. Delay in the start of the operation of the levers of the ejector is ensured by the free movement of the stud which is rigidly fixed to the lift mechanism in the oval slot in the drive lever of the ejector.

After the blanking out of the window aperture, flanging of the component is carried out on a single-action, 500-ton press.

The flanging die is also provided with a pneumatic, mechanical ejector, similar in principle to the former (Fig. 5), but the design of this ejector differs somewhat from that of the ejector used for the removal of the component after blanking the window opening. To a vertical plate, 1, welded to the stand, 2, of the lift mechanism, is attached a lift stud, 3, and to the stand, 2, a lowering stud, 4. Between them is a longitudinal lever, 5, fastened by

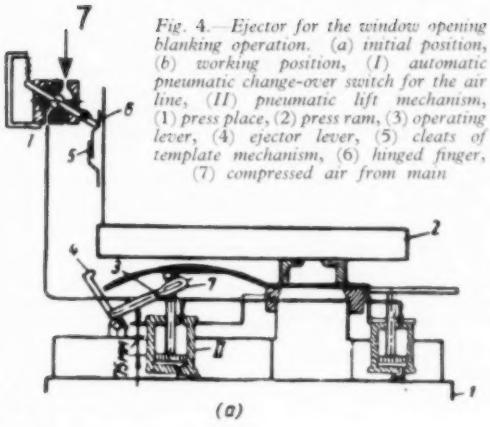
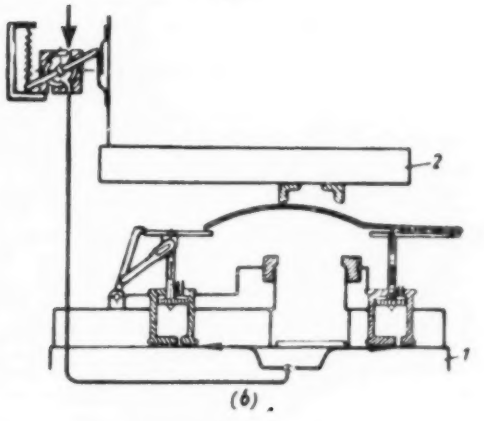


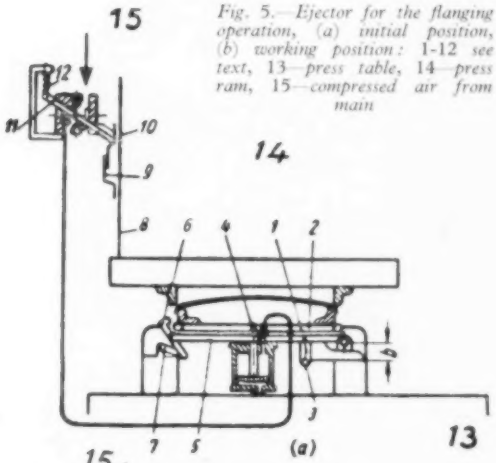
Fig. 4.—Ejector for the window opening blanking operation. (a) initial position, (b) working position, (I) automatic pneumatic change-over switch for the air line, (II) pneumatic lift mechanism, (1) press place, (2) press ram, (3) operating lever, (4) ejector lever, (5) cleats of template mechanism, (6) hinged finger, (7) compressed air from main



a ball joint to the back side of the die. In this way the lifting and lowering of the pneumatic lift mechanism, which removes the component from the flanged sections, causes the free end of the longitudinal lever to describe an arc in the vertical plane. Delay in the start of the movement of the lever, and consequently of the whole mechanism of the ejector, is governed by the distance, *b*, from the bottom edge of the longitudinal lever to the lift stud. At the free end of the lever the double-crank ejector lever, 6, is fastened by a ball joint. The upper crank of this lever is designed to remove the component, while the lower crank is fastened by a ball joint to the intermediate lever, 7, which is again fastened by a ball joint to the bottom plate of the die.

The pendulum movement of the longitudinal lever, 5, involves the movement of the double-cranked lever, which completes a complicated pushing movement due to the intermediate lever. The component is removed from the working zone of the die. The ejector returns to its initial position, as the lift mechanism returns to its extreme, lower position. The lowering stud, 4, during its downward movement meets on its path the longitudinal lever, 5, and moves the latter down along with it. The double-shouldered and intermediate levers, 6 and 7, moving on their ball joints, take up their original positions.

The pneumatic ejectors and pneumatic lift mechanisms are set in motion by compressed air, which passes from the supply line into the working cylinders of the die mechanisms through the automatic, pneumatic change-over switch. The purpose of the automatic, pneumatic change-over switch is to bring into operation at the required moment the lift mechanism or the lift mechanism and the ejector together, dependent on the direction of movement of the ram of the press, and also to set the time during which the pneumatic lift mechanism



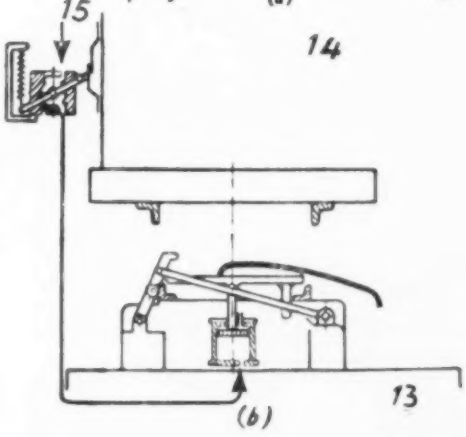


Fig. 5.—Ejector for the flanging operation, (a) initial position, (b) working position: 1-12 see text, 13—press table, 14—press ram, 15—compressed air from main

is held in the working position. This is ensured by the dual control of the template mechanism located on the ram of the press.

The wide metal plate, 8, has four vertical slots, through which pass adjustable clamping bolts, which secure the plate to the ram of the press. A given setting determines the moment when the change-over switch is switched on or off (first regulation). The plate carries a template mechanism, consisting of two cleats, 9, the working surface of which, has a stepped section, upwards and downwards. The position of the cleats can be regulated in relation to the plate, so that they may be moved nearer or further apart, at the same time altering the length of the template mechanism. This makes it possible to set the required time of delay in the operation of the pneumatic lift mechanism (second regulation).

The air-operated change-over switch is itself firmly fastened to the column of the press. The operating lever, 11, is held in its initial position by the spiral spring, 12, during which time the upper cavity of the cylinder is filled with air. The bearing shoulder of the lever is provided with a hinged finger tip, 10, which ensures free passage of the template mechanism during the downward movement of the press ram. During the return movement of the ram of the press the template mechanism runs up against the working shoulder of the lever of the pneumatic change-over switch, and by rotating it lets the air into the bottom cavity of the cylinder. The duration of the sliding of the lever over the template mechanism, which also depends on its length, determines the delay in the delivery of air to the cylinders of the die mechanisms. The use of a pneumatic change-over switch of the given design made it possible to establish mechanised withdrawal of the component from the die by means of the ejector, and completely released the operator from the need to turn the lever of the air change-over switch manually.

Operation of the line is made up as follows. A sheet from a bundle is delivered by two female workers to the shear, is located by the front stop, and is cut into two, one half of which falls onto a car, and the other half is laid by hand on the pile. Passing through the work rolls of the levelling roll stand, the sheet emerges to be gripped by the vertical guides of the sheet piler. Use of the sheet piler released one operative. The pile of levelled sheets is removed from the sheet piler by the bridge crane and placed on a transport grid, the limit stops of which are set in the upper, working position. The grid and the sheets are delivered by the bridge crane to the drawing press. The limiting stops of the grid are placed in the horizontal position.

Two press operators lubricate the sheet and push it into the drawing die, where it is located according to its outline by locating dowel pins. By pressing four knobs the press is switched on, and carries out the full working cycle. During the upward movement of the ram of the press the pneumatic lift mechanism is switched on, and the " mechanical hand," controlled by two electro-pneumatic valves operating from contactor mechanisms connected with the crank mechanism of the press, grips the ejected component and pushes it onto the interstage conveyor. The " mechanical hand " has taken the place of two operatives, engaged in the removal of a component.

Preliminary blanking out of a corner in the flat sheet is carried out on the drawing press at the moment when the faces of the clamp close together by the " floating shears."

Use of the " floating shears " has made it possible to eliminate one operation, free one single-action, 215-ton press, release four press operators, shorten and even out the technological flow, and cut down the consumption of compressed air and electrical power.

The drawn component is taken off the conveyor by two female press operators and placed manually in the blanking die. The press is switched on, and after blanking, the component is removed from the press in a similar way to the previous operation. The " mechanical hand " for removing the component after blanking has replaced one operative. The use of " mechanical hands " for withdrawal mechanisms, pneumatic ejectors and other mechanisms which replace manual labour for the removal of a component from the working zone of the die, considerably reduce operator fatigue.

Placing of the components into the dies for the window blanking and flanging operations is carried out manually. For placing the components into the dies and switching on the presses, one person each is required.

The pneumatic ejector of the flanging die passes the component along a special table to rest against a stop plate. Here the finished component undergoes inspection, and is manually placed in a container by one of the workers.

When full of components, the container is transported by the bridge crane to the loading point onto a trailer truck of the truck tractor. The finished components are delivered by the truck tractor to the required department.

The scrap produced during the manufacture of the components in the drawing and window opening blanking operations is loaded into a container and delivered by the bridge crane for further use.

The final scrap is transported by conveyor and skid to the belt of an underground conveyor, which delivers it to a baling press.

The introduction of the mechanized line has released 11 workers from the technical flow line,

(*Continued in page* 831)

Economic Tooling for Batch Production

By NORMAN FORD*

MULTI-STAGE tooling and batch work do not normally go as a pair. Usually the emphasis is placed on low-cost tools using as many bought-in, mass-produced parts as possible. At the Paddington Green, London works of James Randall and Son Ltd., the approach to each job follows the principle that as many operations as possible should be incorporated in one tool—frequent handling between operations can be more expensive than a multi-stage tool.

Such a policy almost entirely precludes the use of standard die parts. There is ample opportunity though, to cannabalize old tools that were built with this approach in mind. To do this effectively, accurate records are kept of all tools made and the exact operation performed by each one. It is surprising how often old tools need only slight modification to suit a new job. In fact for the subcontract department, which forms as big a part of the company's business as does the manufacture of "Active Storage" equipment, the policy has led to the development, for certain operations, of several standard tools that can be adjusted over a wide range of sizes. Typical of this type of tool is that shown in Fig. 1 which was originally developed

* Works Manager, James H. Randall and Son Ltd.

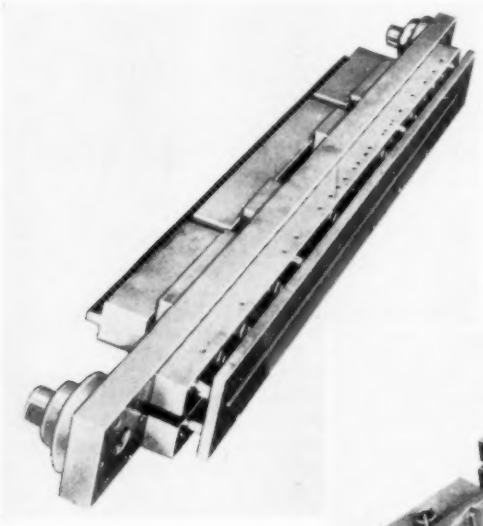


Fig. 1 (above).—Honeycomb panel slotting tool easily adapted to suit one of six different slot lengths. Tool is made in segments, one of which is removed and replaced with a bridge piece to form the third shear

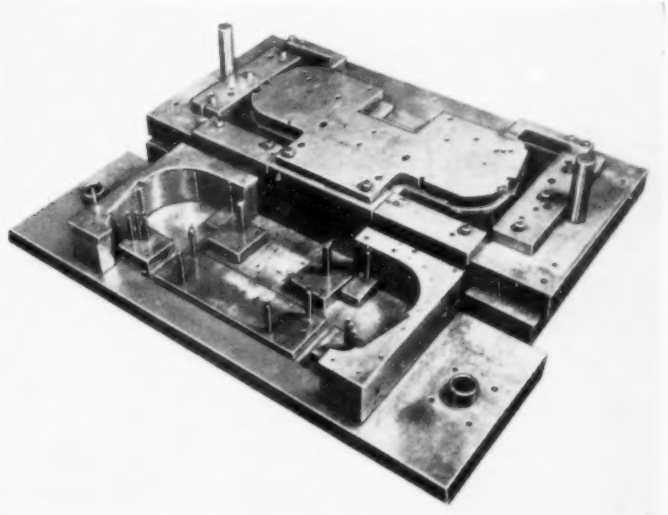
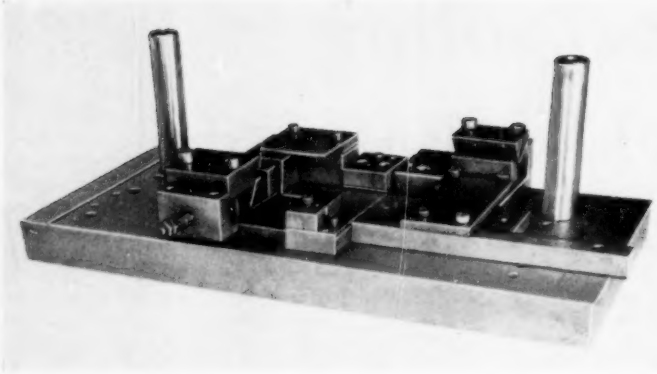


Fig. 2 (right).—This tool was developed for blanking and piercing the combined front and side panels of a towel dispensing cabinet



Figs. 3a (left) and 3b (below).—Four-station progressive tool for producing card clip. This tool has no mass-produced parts

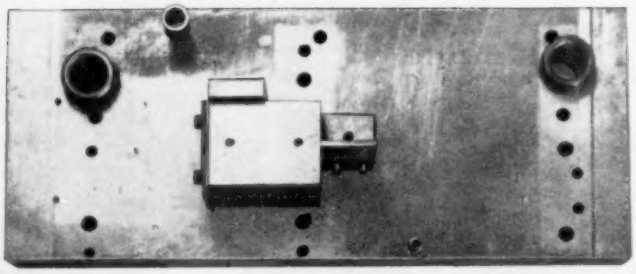
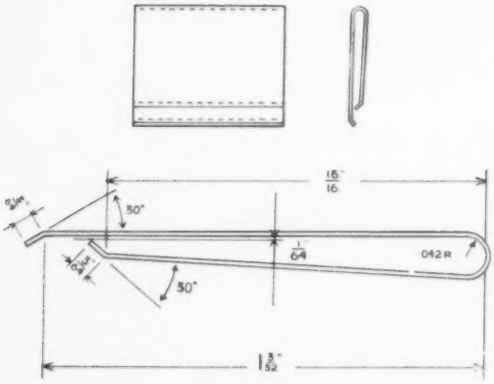


Fig. 3c (below).—Sketch of card clip produced in tool shown in Fig 3a



for cutting slots in the hardboard panels making up the honeycomb in the company's "Planstore" cabinet for storing engineering drawings. This enables six different slot lengths, namely 24, $28\frac{1}{2}$, $34\frac{1}{2}$, $38\frac{3}{4}$, $40\frac{3}{4}$, and $42\frac{3}{4}$ in. to be cut with only a simple modification of the one tool. The top tool is made in segments, any one of which can be removed, and a bridge piece is inserted in the die to form the third shear.

By removing one guide pillar from the tool and fitting standard guide pillars to the brake press, two 24 in. slots can be cut in a 54 in. board. The centre distance between the rows of slots is fixed by a pin stop mounted in the normal way and registering in the slot.

This idea has been developed further for another job frequently in the workshop—bases for electrical cabinets, slotted to provide varying locations for positioning different items of equipment on assembly. The bases are made from 10-s.w.g. mild steel and the pitch between the slots remains constant. The pitch between the rows varies however, and the tool is arranged with a series of punches at different pitch increments. Those not wanted are taken out for operation. Batch quantities as low as 40 off can be catered for very economically in this way.

In contrast, the tool shown in Fig. 2 is for a towel-dispenser cabinet normally processed in quantities from 2,500 to 5,000 at a time. The developed shape of the front and sides of the cabinet is blanked out; holes and slots for fixing the cabinet to the wall are punched; the profile ends notched, and a total of 10 rivet holes punched with one stroke of the press.

A four-station progressive tool (Figs. 3a and 3b) engineered to produce a card clip (Fig. 3c) at quite high production rates is another case of developed

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Tooling for Batch Production

(*Continued from page* 830)

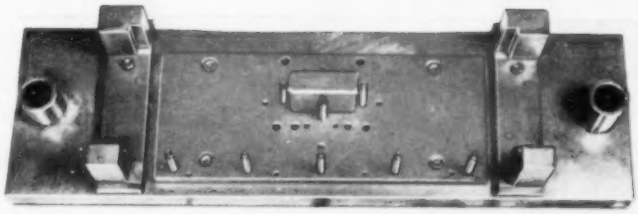

Fig. 4.—Front of the storage drawer is blanked out in one operation with the tooling illustrated. Batch sizes have varied on this job from only 150 *off to as many as* 3,000

tooling, enabling the job to be completely finished with only one handling. At the first station the strip is cropped to correct width and the component almost cut off by notching two slots inwards from each edge, leaving a small tag in the centre to maintain continuity. An off-set each end is folded on a ridge at station 2 and at station 3 the part is folded square and the tag out. Finally at station 4 the fold at the top is closed. The final illustration (Fig 4) shows the tool used for producing the front of a storage drawer in batches that have varied from an original order of only 150 to as many as 3,000 off at a time. Operations included in the one tool are notching the four corners, blanking out the square handle hole, punching four holes for fixing and punching five holes for self-tapping screws.

Mechanized Stamping Line

(*Continued from page* 828)

and has increased labour output by 46 per cent. The full costs for the mechanization of the line, namely 16,240 roubles, were amortized in the course of three months operation of the line.

Technical Data

Annual output of the line operating on a two-shift-system	1,074,500 panels
Number of units of installed equipment ..	8
Of which	
Technical	6
Transport (1 truck tractor and 1 bridge crane)	2
Personnel working on the line per shift ..	14
Of which	
Production operatives	11
Others	2
Storekeepers	1
Number of working strokes per minute:	
750-ton press	6.5
500-ton press	9
400-ton press	10

SIMPLIFIED GRAIN-SIZE MEASUREMENT

VARIOUS elements are used to control grain-size, which is an important factor in determining the characteristics of finished steels. The most widely used is aluminium, which inhibits grain growth by raising the grain coarsening temperature of steels.

The Steelmaking Division of B.I.S.R.A. reports that a conclusion drawn from recent tests is that the measurement of aluminium content of a steel provides a reliable, quick, and less expensive alternative to the McQuaid-Ehn Test for evaluating grain-size.

Recovery of Scale from Rolling Mill

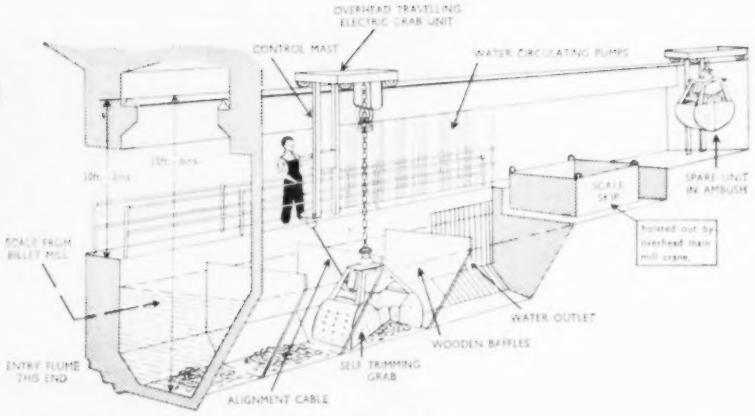

Fig. 1.—Diagram of scale-recovery installation

SCALE formed in the production of stainless and other high-quality steels is very valuable as it contains a high proportion of the expensive alloying metals such as molybdenum, vanadium, cobalt and chromium. Its recovery however, is highly problematical as most of it is removed from the steel billets as they pass through the primary and intermediate mills.

The problem has been solved at the Stocksbridge works of Samuel Fox and Co. Ltd., by the installation of specially-designed recovery grabbing cranes in the scale pit beneath the new intermediate mill. The plant, which was designed and installed by Michael and Partners Ltd., Chesterfield, is so designed that scale, falling from the rolls of the billet mill, is sluiced down by water over a weir and into a settling pit. One of the two crane-operated grabs then dredges the pit and lifts the scale into a waiting skip. The cross-section of the pit is such that the width of the flat bottom is only 2 in. more than the full width of the grabs, thus ensuring almost complete recovery.

The grabs are of the self-trimming type, originally designed for the complete unloading of coal from railway wagons to obviate hand trimming so that almost every particle of scale that lies in the course of the grabs' jaws is removed. The self-trimming characteristic of the grabs enables them to cover almost all the bottom area between the baffle boards without danger of displacing them.

One difficulty encountered in the design of the equipment was the very low headroom available. Grabs of the special ring discharge type were designed having a fixed discharge height but a variable loading height.

The grab hoisting and traversing motions are controlled from a push-button panel, of Geipel manufacture, mounted on a fabricated mast, attached to the crab frame and easily operated from the walkway extending along one side of the scale pit. The motions indicated on the panel are: hoist and lower; travel right and left; with an overriding stop.

The grabs are of mild-steel all welded construction, with hard facing on clamshell jaws, which pivot on high-tensile pins running in steel taper-wedge bushes. The grab arms are of special flexible design and terminate in a double pivot-top pulley box centralized by extended interlocking fingers. As the grabs lift the scale from under water, the clamshells, crosshead and pulley box are self draining. The grabs have 4:1 reeving and a special chrome molybdenum alloy chain is used with precision cast steel chain wheels and special automatic locking mechanism. A high-pressure greasing system with water repellant grease is used.

The grabs have a level struck capacity of 7.5 cu. ft. and an unladen weight of 17 cwt. Each grab is suspended from a special electric overhead travelling crab unit supplied by George W. King Ltd., of Stevenage. These crab units, complete with travelling control mast, are of the overslung 4-wheel type incorporating a "Mamouth" precision chain pulley lifting block and operating on a 6-ft. 6 in. gauge cable, reeled on and off coiling drums into cable ducts alongside the crane track.

Although only four or five grab loads of scale are removed from the pit each working day, Samuel Fox and Co. Ltd. asked for two complete units to be installed so that one could be used as a stand-by.

Operation

The grab is raised by pressing the " lift " button on the pendant control panel until the discharge flange or ring engages in the two suspension hooks. A limit switch is incorporated so that should hoisting continue after this position is reached it will automatically cut out. When the " lower " button

(*Continued in page* 833)

Quantitative Assessment of Deep-Drawing and Stretch-Forming Qualities—References

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The Production of a Special Deep-Drawn Electric Motor Cover

(*Continued from page* 812)

associated with such tools, and this particular example is only just within the economical design factor; it was expected that little maintenance would be necessary as the quantity of pieces is limited and the comparatively thin gauge of the material meant the absence of heavy punching.

For large-scale production this type of shell is an excellent case for transfer loading, a Schuler press being an ideal machine for the work, and it is suggested that these tools would require little modification for such a change in manufacture.

Rolling-mill Scale Recovery

(*Continued from page* 832)

is pressed the grab becomes fully opened and the lifting chain slackens. The grab is then locked in the open position.

The " lift " button is pressed momentarily until the discharge flange of the grab rises just above the suspension kicking horns and the button is pressed again. The " lower " button is then pressed to allow the grab to descend into the stock until the hoist chain slackens.

When the grab has come to rest on the stock to be lifted and the hoist chain slackens, the " lift " button is pressed and the grab automatically closes, filling itself in the process. The grab is hoisted clear of the settling pit and allowed to drain before hoisting to the discharge position and traversing down the chamber to the scale disposal skip where the contents are emptied by opening the grab as above. The skip is lowered and raised from its position in the pit by an overhead travelling crane in the mill building.

INSTITUTE OF SHEET METAL ENGINEERING

ANNUAL CONFERENCE AND EXHIBITION

Imperial Hotel, Birmingham, November 7, 8, and 9. 1961

THE Annual Conference of the Institute of Sheet Metal Engineering, with which will be associated the twelfth Exhibition of Sheet Metal Working Equipment and Techniques, will be held this year at the Imperial Hotel, Birmingham, on Tuesday, November 7, Wednesday, November 8, and Thursday, November 9.

The Exhibition will be open and visitors will be welcome at all normal hours during the period of the Conference.

Programme

Tuesday, November 7

11.30 a.m. Official opening of the 12th Exhibition of Sheet Metal Working Equipment and Techniques in the Connaught Room of the Imperial Hotel by E. W. Hancock, Esq., O.B.E., President of the Institute.

2.15 p.m. 1st Technical Session—**General Presswork.**
Paper: "Use of Dry Soap Film Lubricants for Deep Drawing" by J. Clarke (R. Cruickshank Ltd.)
Paper: "Tool Steels for High Speed Presswork" by A. W. F. Comley (Wilmot Breeden Laboratories).
Paper: "Methods of Rating Power Presses" by E. Hamilton (Wilkins and Mitchell Ltd.).

Wednesday, November 8

9.30 a.m. 2nd Technical Session—**Problems of Feeding in Modern High Speed Presswork.**
Paper: "The Sprag Clutch as an Aid to Accurate Press Feeding" by G. F. Newman (Renold Chains Ltd.)
Paper: "The Swift Feeder Unit" by D. L. Dennison (Birmingham Tool and Gauge Co. Ltd.)
Paper: "The B.N.F.M.R.A. Roller Stretcher Machine as an Aid to High-Speed Press Feeding" by D. Boxall (British Non-Ferrous Metals Research Association.)

1.00 p.m. Buffet Luncheon.

2.15 p.m. 2nd Technical Session (continued).
Paper: "Problems Associated with the Production of Aluminium Pressings for Bottle Closures" by W. H. Hadley (Metal Closures Ltd.)
Paper: "Development of Roller Feed Mechanisms for Coiled Strip" by H. F. Hawkins and R. J. Lloyd (Humphris and Sons Ltd.)

Thursday, November 9

9.30 a.m. 3rd Technical Session—**Feeding, Slitting and Processing of Heavy Wide Coils in Rolling Mills, Press Shops and Warehouses.** Discussion on this highly topical theme will be initiated by the presentation of five papers outlining the relevant problems and techniques from the following differing points of view:

1. The Steel Strip Producer. S. Gray (John Summers and Sons Ltd.).
2. The Aluminium Strip Producer. R. W. Hilditch (Alcan Industries Ltd.).
3. The Equipment Manufacturer. J. F. Lyden (The McKay Machine Co., U.S.A.).
4. The Press Shop. D. C. Finch (Pressed Steel Co. Ltd.).
5. The Stockholder. A. I. Shenkman (Scottish Steel Sheet Co. Ltd.).

1.00 p.m. Buffet Luncheon.

2.15 p.m. 4th Technical Session—**Deformation of Metals at High Rates of Strain.**
Paper: "The Effect of Strain Rate on the Tensile Stress-Strain Characteristics of Metals, and some Practical Implications" by H. G. Baron (A.R.D.E.)
Paper: "The Rapid Determination of Strain Rate Effect Using a Dynamic Indentation Technique" by C. D. Davis and S. C. Hunter (A.R.D.E.).

ONE-DAY CONFERENCE ON SHEET-METAL TESTING

Under the aegis of the Test Panel of the British Deep Drawing Research Group a one-day Conference will be held at the City and Guilds College on December 19, 1961, devoted to the presentation and discussion of a number of papers relating to important aspects of sheet metal testing. The testing of sheet metal with a view to predicting its behaviour under the press has been fast assuming great significance in industry throughout the world, and the appraisal of established tests as well as the quest for improved ones has been the major occupation of the panel in recent years.

The papers to this Conference will not be preprinted but will be presented in full at the meeting, which will provide an invaluable opportunity for full discussion on this vexed topic.

The programme as planned at present includes the following papers.

"Metal Properties Relevant to the Forming of Sheet" by J. M. Alexander, Ph.D., B.Sc.Eng. (Reader in Plasticity, City and Guilds College.)

"Factors of Importance in Simulative Testing" by J. F. Wallace, Ph.D., B.Eng. (Pressed Steel Co. Ltd.)

"The Tensile Test as a Guide to Forming Properties" by R. Pearce, B.A., B.Sc. (College of Aeronautics.)

"Current Views on the Scope and Application of the Swift Test with Some Reference to Other Cupping Tests" by D. V. Wilson, Ph.D. (Birmingham University).

"Appraisal of Current Information on the Erichsen Test" by L. Hawtin (I.C.I. Ltd., Metals Division.)

"Appraisal of Current Information on the Olsen Test" by D. H. Lloyd (Fisher and Ludlow Ltd.)

Detailed programme and application form for tickets for this Conference will be circulated in the near future to all members of the British Deep Drawing Research Group. Others interested should apply to the Hon. Secretary, Institute of Sheet Metal Engineering, John Adam House, John Adam Street, Adelphi, London, W.C.2.

SHEET METAL NEWS

FEATURING EVENTS AND PERSONALITIES IN THE INDUSTRY

NEW U.K. MANUFACTURING FACILITIES FOR POWER PRESSES

Senior American Vice-President of Clearing Visits Vickers' Scotswood Works

NEW facilities for the manufacture of power presses and associated equipment have been completed at the Scotswood works of Vickers-Armstrongs (Engineers) Ltd., Newcastle-upon-Tyne. The new Power Press Division has been formed to satisfy increasing demand for presses designed by the Clearing division of U.S. Industries, Inc., manufactured by Vickers-Armstrongs (Engineers) Ltd., and sold in the U.K. under the name British Clearing by Rockwell Machine Tool Co. Ltd. The division also manufactures associated equipment, including Vickers-McKay metal-processing equipment.

Work formerly carried out at two different plants has been consolidated into one and a considerable investment in new plant and equipment has been made by Vickers in order to increase productive ability and efficiency. The division occupies about 22 acres, and the works are equipped to fabricate up to 12 in. thickness of plate and have produced welded structures up to 100 tons in weight. The machine shop handles complete processing of the great variety of components required for products, from the smallest turned pins to the massive fabrications which are faced, milled and bored on large horizontal borers.

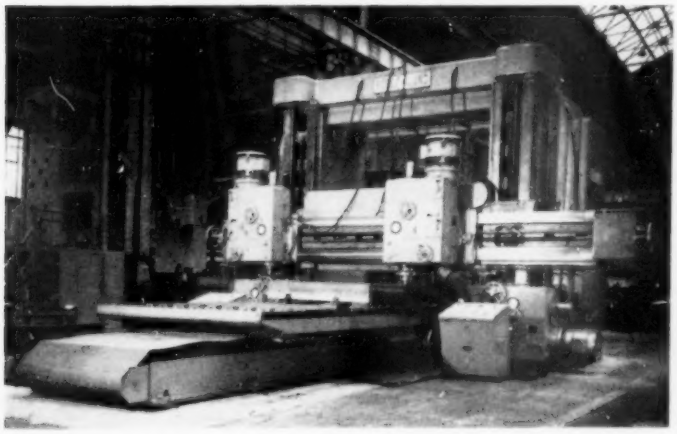
(Above).—Two 7-in. dia. spindle Giddings and Lewis floor-type milling, drilling and boring machines

Mr. E. P. Cunningham, senior vice-president of the Clearing division of U.S. Industries, Inc., and Mr. A. J. Wardle, Jr., president of the McKay Machine Co., saw the newly laid-out and completed facilities when they visited the Scotswood works on Tuesday, October 3. Guests on this occasion were welcomed by Commander R. B. Lakin, D.S.O., D.S.C., assistant managing director of Vickers-Armstrongs (Engineers) Ltd., responsible for the northern works.

Mr. Cunningham said that Clearing believed that the substantial operation which had developed from their association with Vickers-Armstrongs and Rockwell Machine Tool Co. was a splendid example of Anglo-American co-operation. The partnership had made an advanced press design available to users in the United Kingdom, while conserving dollars to the utmost extent and, at the same time, promoted a substantial volume of exports from the United Kingdom to many parts of the world.

The first Clearing press was designed and built in 1933 and from this comparatively recent beginning the company has grown to the

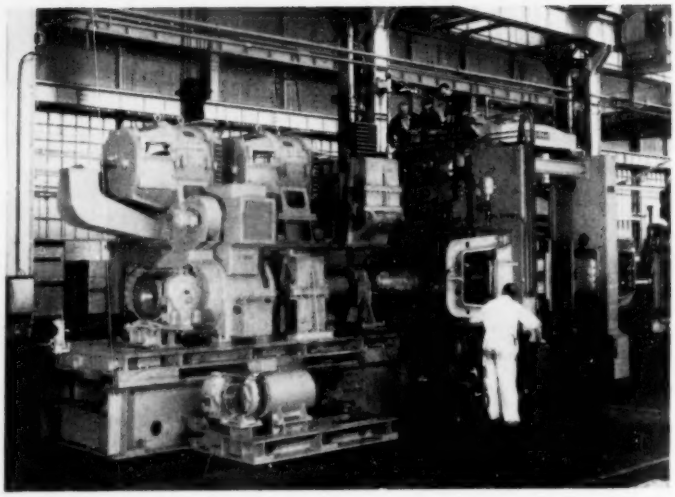
(Continued in page 836)



(Left).—Two large Plano-Milling machines, finish machining a bolster plate for a Clearing press

Vickers' Scotswood Works

(*Continued from page* 835)



(Right).—Part of a Vickers-McKay 12-in. × 8-in. × 78-in. special processing uncoiler undergoing shop trials

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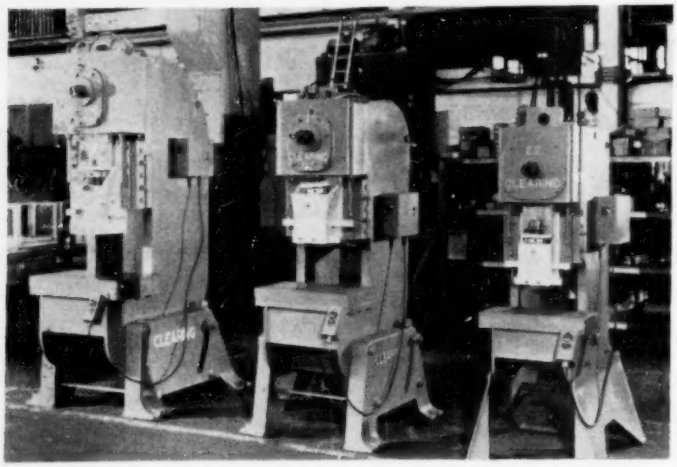
(Below, left).—Three of the range of British Clearing open-back inclinable Torc Pac presses, built at Southern Works

position it occupies to-day. In its 11-acre plant in the Clearing industrial district of Chicago, a very wide range of mechanical and hydraulic presses for the metalworking industry are designed and manufactured.

From 1934 up to the outbreak of World War II, Clearing exported a substantial quantity of presses to the United Kingdom. At the end of the war changed conditions demanded a new approach if the company was to compete successfully with press manufacturers throughout the world. This resulted in the now well-established collaboration between Vickers, Clearing and Rockwell. Since 1946, when production commenced at Newcastle, British-built Clearing presses have been installed in many press plants in the United Kingdom and the automobile industry particularly have been large customers.

Recent new developments include the Torc Pac 40 clutch and brake unit for large power presses, designed to facilitate higher rates of production with a major reduction in down time. For this clutch, Vickers-Armstrongs have created special manufacturing facilities at Scotswood. The second is the new range of Torc Pac open-back inclinable presses which are being produced by Vickers-Armstrongs at their Crayford works in Kent. These presses are currently being manufactured in 22, 32, 45 and 60 ton capacities, and represent a new approach to small press design.



Vickers-McKay Metal Processing Equipment

Vickers-McKay Ltd. was founded in 1958 as a joint venture between Vickers-Armstrongs (Engineers) Ltd., McKay Machine Company, Youngstown, Ohio, U.S.A. and Rockwell Machine Tool Co. Ltd., London, to manufacture, within the facilities of Vickers-Armstrongs (Engineers) Ltd., and market products designed by McKay Machine Company.

McKay design and manufacture a wide range of products in the metal-processing field including press-feed lines, cut-up lines, tube-manufacturing machinery and machines for forming corrugated and other sections of steel or aluminium.

The largest field of McKay activities has been in the automotive industry where new techniques are completely changing the method of producing the sheet steel blanks used in making car bodies. The old method was for the steel mill to supply, or the press shop to cut on a manually loaded guillotine, a sheet of the size required. This sheet was in turn manually loaded into a blanking press which stamped out the shape necessary to form, on further presses, a finished panel such as a car door.

Steel coils up to 20 tons in weight and six feet in width can be mounted on a Vickers-McKay decoiling line. The material is then processed through a washing machine, a levelling or flattening machine and then metered accurately into a press.

(*Continued in page* 837)

WORLD REGISTER OF PRODUCTION ENGINEERING RESEARCH

IN 1960, PERA made a special study of the need which exists for a World Register of Production Engineering Research to assist research workers and production engineers to keep fully informed about investigations carried out in research organizations, industrial firms, universities and colleges throughout the world. The study embraced the scope of such a Register, the work involved, the financial and material resources and the form in which it should be compiled and published.

The World Register will cover all production research carried out in the years 1959-62, and will summarize plans for research for the following three years. The main subjects to be covered are:—automation, machine tools, materials handling, finishing processes, metal forming, assembly, inspection and measurement, metal cutting, machinability and formabilty of materials.

The Register will give as much information as can be obtained about establishments carrying out programmes of research revelant to production engineering, including details of the researches undertaken, the staff, workshops, laboratories, special facilities and equipment. The survey is also expected to provide information on publications, educational services, etc. This information will be sought by means of a questionnaire which is now being sent to research establishments, industrial organizations, universities, colleges and trade associations in many parts of the world.

Organizations carrying out any form of production engineering research are invited to write to The Information Manager, PERA, Melton Mowbray, Leics. for a copy of the questionnaire. This will help considerably in making the Register a complete international record of production engineering research.

A complete World Register published in various languages will reduce the risk of investigations being duplicated in different parts of the world. Furthermore, by removing language barriers, it will greatly facilitate continuous contact and communication between scientists and engineers concerned with production.

Vickers' Scotswood Works

(*Continued from page* 836)

Blanks are produced at the rate of 50 per minute, two pieces being produced at each stroke of the press. A manually loaded press can produce a maximum of only 20 pieces per minute. There is a considerable scrap reduction compared to using a rectangular sheet, and furthermore, coiled material is approximately £2 per ton cheaper than sheet.

A similar but more compact line has also been developed. Known as the McKaymatic die shear line, this incorporates a flying shear of novel design which accurately cuts sheets to length under control of a transistorized miniature electronic "brain." Any length from 12 in. to 999 in. can be programmed manually or by punched cards or other information storage methods. The average output is approximately 15 tons of sheet per hour at the rate of 30 per minute. A useful auxiliary machine is a slitting line which cuts wide coils into several narrow ones. Further equipment produced by Vickers-McKay for the automotive industry are several automatic lines for rolling wheel rims for all types of motor vehicles. Additional rim rolling lines are at present in hand.

Vickers-McKay have also manufactured a large number of special purpose levellers known as "Flex-Roll" machines which alter the grain structure of steel to make it more suitable for deep drawing in a press.

McKay also manufacture certain equipment for the Wean Engineering Co. of Warren, Ohio, for continuous pickling, galvanizing, electrolytic tinning and high-speed shear lines. Vickers-McKay at present have in hand some large units of this type for the British steel industry. The new Colville continuous sheet steel mill installation at Ravenscraig, Scotland, will contain six large uncoiling, upcoiling and levelling machines designed by McKay and built by Vickers-Armstrongs (Engineers) Ltd. for Wean-Miles Ltd., British associates of Wean Engineering. Four of these units (one of which weighs 90 tons) have been delivered and similar equipment destined for Scotland and South Wales is at the moment in various stages of completion.

AGENCY

SHEET METAL MACHINERY CO. LTD., Poyle Road, Colnbrook, Slough, Bucks, have been appointed exclusive distributors in Great Britain for the Rotex Punch Co. Inc., of California.

TI ACQUIRES 280-ACRE SITE

TUBE INVESTMENTS LTD. announce the acquisition of a 280-acre site at Washington, Co. Durham, for the long term development of its manufacturing capacity. The decision to purchase has been taken after full consultation with the Board of Trade, the local Authorities and the district officials of the Trades Unions concerned. It is expected that preliminary site work will begin early in 1962 and that by 1965 some 750 men and women will be employed in the manufacture of steel tubing.

The first factory will house a highly mechanized electric resistance welded tube mill incorporating many advanced engineering features. Subsequent factories will be erected in accordance with a development programme for the production of steel tubes and other TI products. The ultimate labour force is expected to exceed 3,000.

HYDRAULIC MULTIPRESSES BEING MANUFACTURED IN BRITAIN

THE Denison hydraulic Multipresses Models R, S and T are now being manufactured in this country by the Denison Deri Co. of Burgess Hill, Sussex. A variety of press capacities from 1 to 12 tons can be supplied, together with various control valves and operating controls. Full details and catalogues are available from the sole agents in Great Britain—Gaston E. Marbaix Ltd., Devonshire House, Vicarage Crescent, London, S.W.11.

BLACK AND DECKER ACQUIRE POWER TOOL FIRM IN ITALY

ITALY'S most important electrical power tool manufacturer, Star, has been acquired by Black and Decker Ltd. It is claimed that this move will increase U.K. exports to the European market and give the company as a whole a commanding position there.

The Star plant, located at Civate in the Italian Alps, near Lake Como, has an area of 86,000 sq. ft. It is of the most modern design and further expansion could nearly double size of the plant on its present site. Sales of Star products in 1961 are estimated to total $2 million.

The merger will be accomplished by an exchange of Black and Decker common stock for the stock of Star. Last year, Black and Decker Ltd., the U.K. company, announced profits of over £600,000—nearly twice that of their nearest competitors.

OLDEST WORKING OXYGEN PROFILING MACHINE

SHOWN above is the oldest working Hancock oxygen cutting machine, manufactured and supplied in 1924 to Davies Brothers and Co. Ltd., of Wolverhampton, who won the recent competition to find the oldest working Hancock machine in Britain. They were presented with a new oxygen cutting machine as a prize.

The machine in the photograph was recently presented to the Museum of Science and Industry in Birmingham by Professor E. C. Rollason, Professor of Industrial Metallurgy at the University of Birmingham. It is a ratio cutting machine which will cut thicknesses of steel plate up to 4 in. Operated by coal gas, it is clockwork driven and the speed is controlled by a spring governor control with a range of 6 in. to 14 in. per min. To obtain accuracy, a drawing is made twice the size of the job required. The motor is wound up, the burner lit and the cutting begins. The operator traces round the drawing keeping an eye on the drawing itself and on the burner to check that the speed is correct.

DUMBARTON FACTORY FOR B.O.C.

BRITISH OXYGEN have agreed with the Board of Trade to lease a site near Dumbarton on which to establish progressively a new light engineering factory, while leaving the oxygen plant manufacturing at the existing Edmonton Works.

It is estimated that over two years will elapse before the first stage of the new factory is established. Thereafter, there will be a gradual build-up to a total strength of about 2,000 during the following three or four years.

RUSSIANS ORDER MORE BRITISH EQUIPMENT

THE Bronx Engineering Co. Ltd. has, during recent weeks, received orders totalling £90,000 from overseas. Stankoimport, Russia, has placed a £45,000 order for plate bending rolls. From Finland a £24,000 order has been received for two large tube straightening machines for copper tubes. Orders worth £14,000, also for tube straightening machines have come from Czechoslovakia, and a similar order worth £7,000 from Switzerland.

NEW METALS BRING NEW RISKS

Chief Inspector's Warning in Industrial Health Report

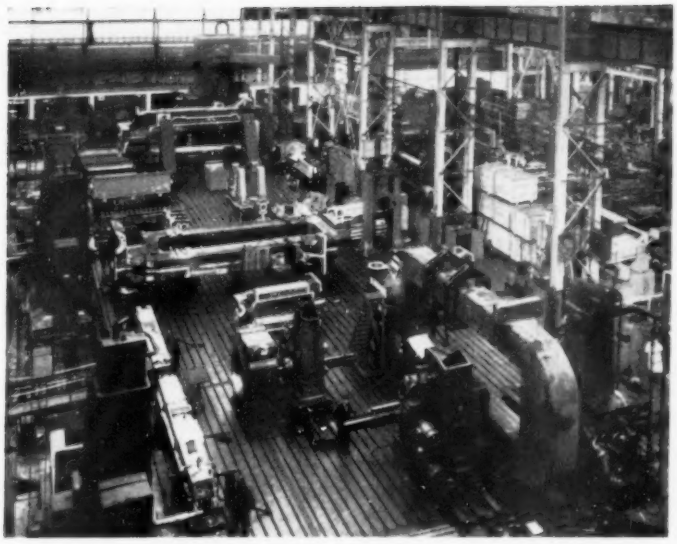
AN instance of the constant watchfulness exercised by Factory Inspectors against health risks which might arise from the growing use of newer metals in industry is given by Mr. T. W. McCullough, O.B.E., H.M. Chief Inspector of Factories, in presenting his Annual Report for 1960 on Industrial Health. (Cmnd. 1478, obtainable from H.M. Stationery Office, or through any bookseller, price 3s. 6d. net.) The report refers to the increasing use of copper-based beryllium alloys, and the action taken by Inspectors to keep the matter under close review and give appropriate advice on precautions to be taken against health risks caused by dust and fumes. It also points out that in manufacturing beryllium on a large scale to meet demands in the atomic energy field elaborate environmental and personal precautions have to be observed.

As in previous years the report reviews the events of the year, and gives details of industrial diseases, poisoning and gassing. The special subject dealt with is a survey of the more important organic solvents and the health risks arising from their use in industry.

Three-Day International Conference on Stud Welding

WHAT is probably the only international gathering of its kind for an exchange of ideas on stud welding was held recently. This was an Overseas Licensees Reunion organized by Crompton Parkinson (Stud Welding) Ltd. and their American associates, Gregory Industries Ltd., Lorain, Ohio, and attended by representatives from fifteen countries.

The party travelled to South Wales to study manufacturing methods at the Glanamman Works where an exhibition of stud welding equipment was held and demonstrations of new techniques took place. Next was a two-day conference which enabled a considerable amount of valuable technical "know-how" to be exchanged. Stud welding applications and techniques affecting the many countries concerned were discussed, the field experience present covering climatic differences as far apart as Finland and Australia.



(Left).—Several rolling-mill units having a total weight of 580 tons undergoing simultaneous machining on the workplate in No. 5 bay

ROLLING-MILL CONSTRUCTION ON SHOW

A Visit to Davy-United Darnall Works

CURRENT orders for rolling-mill equipment, totalling about £25 millions were seen recently in various stages of construction at the Darnall Works, Sheffield, of Davy and United Engineering Co. Ltd., a member of the Davy-Ashmore Group. Darnall works is also the headquarters of Davy and United Instruments Ltd.

During the visit a tour was made of the pattern shop, smith's shop, fabricating department, machine shops, erecting shops, the workshops of Davy and United Instruments Ltd., and the apprentice training school.

Davy and United Engineering Co. Ltd. has concentrated its resources mainly on the building of capital equipment for the steel and non-ferrous industries, and comprises three main Divisions. The first of these, the Machinery Division, is primarily concerned with the engineering of rolling mills, forging presses, and other associated machinery for the deformation of metals. It operates two major engineering works in Sheffield and Glasgow. These works, both of which are notable for their ability to handle single pieces of great weight, together represent well over half of the total designing and manufacturing capacity in Great Britain devoted to this specialized branch of heavy engineering. Another works of lighter capacity is also operated at Glasgow.

The Construction Division, located at Sheffield, is organized to undertake contracts in any part of the world for complete steelworks or complete departments within a steel works, and offers an overall engineering service to any steelmaker planning a development project. One of its principal concerns has been the conduct of Davy-United's share of the contract for the new integrated iron and steelworks at Durgapur in West Bengal, built for the Indian Government.

The Steel Processes Division engineers and supplies oxygen steelmaking plant up to complete melting shops and also offers metallurgical and technical surveys to assist any company contemplating the introduction of oxy-steel processes. The services offered by both these Divisions are supported by the design and manufacturing resources of the Machinery Division.

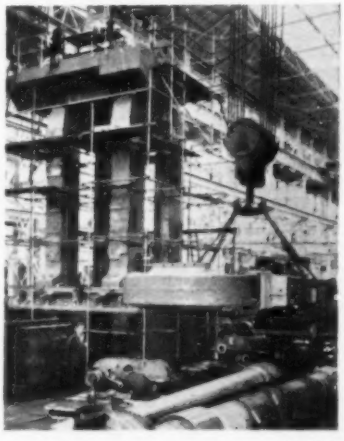
Davy and United Instruments Ltd., which shares the Darnall Works site at Sheffield, has developed a range of instruments of both electronic and radio-active type, which are capable of controlling strip rolling mills automatically, as well as other steelworks processes. The principles employed have been found to have much wider industrial applications.

At Middlesbrough, Davy and United Roll Foundry Ltd. makes all types of chilled, grain, steel base and cast-steel rolls for the rolling of steel and non-ferrous metals and is also equipped to produce steel castings for general engineering, steelworks and marine applications up to a finished weight of 12 tons.

Other companies in the Davy-Ashmore Group are Ashmore, Benson, Pease and Co. Ltd., builders of blast furnaces and other plant for the iron, steel, chemical and related industries, with extensive works at Stockton-on-Tees; The Power Gas Corporation Ltd., designers and suppliers of plant for the gas, chemical, fertilizer, petrochemical and oil industries, with engineering offices at London and Stockton; and Rose, Downs and Thompson Ltd. of Hull, who make plant and equipment for milling, extracting and processing in the animal food and technical and edible oil industries.

(*Continued in page* 840)

(Below).—One of the finishing stands of the hot-strip mill for Spencer Works under construction at the Darnall Works of Davy and United



HUNGARIANS INCREASING ROLLED STEEL OUTPUT

IMPROVEMENTS suggested by a foundry committee of the Mutual Economic Aid Council (Comecon) should double output of Hungary's rolling mills at Diósgyór and push up production at the Ózd rolling mills by 30 per cent within the next five years.

Hungarian foundry technicians have added their own ideas to the committee's suggestions, and it is anticipated that without considerable capital investment national output of fine rolled goods can be increased by 56 per cent.

Re-equipment of the Lenin Foundry Works at Ózd, in Northern Hungary, is making good progress. Four of the new Marz type Martin furnaces are in production and a fifth should be in operation by the end of this month. Three more furnaces to be installed between now and next March should complete the new line two months ahead of schedule.

Visit to the Darnall Works of Davy-United

(*Continued from page* 839)

A substantial overseas organization also exists in the shape of further subsidiary companies in Africa, Australia, Canada and France. These companies undertake the supply and erection in the countries concerned of the types of plants manufactured by Ashmore, Benson, Pease and Co. Ltd. and The Power Gas Corporation Ltd.

The co-ordination of the extensive overseas organization of the Group is undertaken by Davy-Ashmore Export Co. Ltd. from its office in London.

The main rolling-mill contracts at present being undertaken by Davy and United are briefly outlined below:—

Colvilles Ltd.

Ravenscraig: 68 in. semi-continuous hot-strip mill, having an initial output of 500,000 tons of strip a year and designed for an eventual output in excess of 1½ million tons a year.

Gartcosh: Working in conjunction with this hot mill will be new cold-rolling mills at Gartcosh, comprising a 21 in. and 56 in. × 68 in. 4-stand tandem cold-strip mill and a 22½ in. and 56 in. × 68 in. single-stand temper mill. Extensive Davy-United instrumentation is being supplied for both mills, including automatic gauge control for the tandem mill.

Clydebridge: 39 in. and 60 in. × 132 in. 4-high plate mill which will produce plate 120 in. wide and up to 90 ft. long.

Lancashire Steel Manufacturing Co. Ltd.

22-stand wire rod mill designed for 4-strand operation. Contract value exceeds £1 million.

Richard Thomas and Baldwins Ltd.

Spencer Works: 68 in. continuous hot-strip mill with an initial output of 1 million tons of strip a year and designed for an eventual output of around 3 million tons a year.

The Steel Company of Wales Ltd.

Abbey Works: 21 in. and 53 in. × 56 in. temper mill.

Aluminium Industrie A.G.

Chippis Works, Switzerland: 32 in. and 57 in. × 98 in. 4-high hot breaking down and plate finishing mill.

Imperial Aluminium Co. Ltd.

Waunarlwydd Works: 21 in. and 55 in. × 72 in. 4-high single stand hot mill, designed to work with an existing Davy-United hot mill, and a 16 in. and 55 in. × 72 in. 2-stand tandem cold-strip mill.

English Steel Corporation Ltd.

Tinsley Park Works: Acting as a consortium, Davy and United Engineering Co. Ltd. and The Brightside Foundry and Engineering Co. Ltd. have recently secured a contract worth just over £2¼ million to build rolling mills required for the new Tinsley Park Works. The plant is designed primarily for the quantity production of high quality alloy and special carbon steel billets. It consists of a 42 in. × 102 in. blooming and slabbing mill which Davy-United is building, two 32 in. × 84 in. reversing billet mills and extensive billet finishing equipment.

Koninklijke Nederlandsche Hoogovens en Staalfabrieken N.V., Holland.

44 in. × 102 in. blooming and slabbing mill.

Interesting rolling-mill contracts now in progress in the Instrument Company workshops are:—

8 gamma-ray thickness gauges for installation in plate and strip mills in the U.S.S.R.

Automatic gauge control and complete instrumentation for the 4-stand cold-strip mill at the Gartcosh Works of Colvilles Ltd.

Automatic gauge control for a 4-high cold reversing mill at The Steel Company of Wales Ltd., Newport Works.

Seven sets of loadmeters for a hot-strip mill at J. Summers and Sons Ltd.

UNITED STEEL SCHOLARSHIPS

THE United Steel Companies Ltd. have awarded five university scholarships, following a final selection board held in Sheffield, at which a short list of twenty candidates was interviewed out of a total of 201 applicants.

The scholarships are tenable for three or four years and are to the value of £500 per annum, free of tax. It is intended that they should provide industrial as well as academic training, and arrangements will be made for the successful candidates to receive industrial experience with the company.

This is the second annual award of United Steel scholarships: five were awarded in 1960.

The scholarships were awarded to:—

J. S. Briggs of Thornes House School, Wakefield to Manchester University.

B. Cheetham of King Edward VII School, Sheffield to Corpus Christi College, Oxford.

R. A. Herbertson of Magdalen College School, Oxford to Corpus Christi College, Oxford.

L. M. Jones of Oswestry High School for Boys to Trinity College, Cambridge.

R. M. Sainsbury of Sherborne School to Corpus Christi College, Oxford.

8th International Hardware Trades Fair

THE 8th International Hardware Trades Fair to be held at Olympia from May 14 to 18, 1962.

Goods from all over the world will be on display alongside Britain's own developments in almost every section of this industry, which exported over £158 millions of equipment during 1960, and exports for the period of January to July this year show an increase of 11½ per cent when compared with those for the same months in 1960.

Further details are available from the organizers, Universal Exhibitions Ltd., 74 Holland Park, London, W.11.

AMALGAMATION OF OWEN AND DYSON WITH STEEL, PEECH AND TOZER

THE assets and liabilities of Owen and Dyson Ltd. have been transferred to The United Steel Companies Ltd. The business of Owen and Dyson is now being undertaken by Steel, Peech and Tozer, and the new department thus created will be known as the Fullerton machine shops.

OBITUARY

Death of Mr. W. S. Grainger:

His many friends in the sheet metal and vitreous enamelling industries will have heard with regret of the death on Thursday, October 5, of Mr. W. S. Grainger. Mr. Grainger was a founder member of the Institute of Sheet Metal Engineering and until his retirement continued to play a significant and much valued part in furthering its work and progress. He was an inspiring Chairman of its Council during its early formative years and had been an Honorary Vice President since 1954.

Mr. Grainger spent the whole of his life in the vitreous enamelling industry and in addition to being a founder member of the industry's employers Association, he also contributed greatly to the inauguration of the Institute of Vitreous Enamellers in 1934. He was a past chairman of Council of the I.V.E. and served it as Honorary Treasurer for the greater part of its existence. It was a fitting climacteric to his years of devoted service to that body that he was elected its President at the 1960 General Meeting. It was in that capacity that he attended the Annual Dinner of the Institute at the City Livery Club in London only a few days before his death. It was obvious at that time to all present that he was very frail and that he must have made a very serious effort in journeying from his home in Devon. This, however, was in keeping with the very great importance which throughout his life he attached to the duties associated with public office.

Although he sold his enamelling works about eighteen months ago and retired from active business he retained his keen interest and enthusiasm in the ventures with which he had been associated to the very end.

Mr. W. S. Grainger

Death of Sir Ellis Hunter:

Hunter: We regret to announce the death of Sir Ellis Hunter, chairman of Dorman Long and Co., Ltd., and its principal subsidiaries, and president of the British Iron and Steel Federation from 1945 to 1953. Born on February, 1892, he had been a leading figure in the iron and steel industry for many years. He played a major part in formulating the industry's Plan of Development, which was submitted in 1945 and later approved by the Government and published as a White Paper. He was knighted in 1948 and was made K.B.E. this year.

Sir Ellis, who had been chairman since 1948 and was also managing director of Dorman, Long and Co., retired at the end of March from all executive appointments in the group, including the joint managing directorship of Dorman Long (Steel) Ltd. It was then announced that he would continue as chairman of the parent company and its principal subsidiaries.

He had been a member of the board of Dorman, Long and Co. since 1938, when he was also appointed deputy chairman of the company. In 1945, the year in which he was elected president of the British Iron and Steel Federation, Sir Ellis became the first chairman of the British Steel Producers' Conference.

Sir Ellis, who was educated privately, qualified as a chartered accountant in 1913, and during the first world war he worked with the Ministry of Munitions on iron and steel works extensions. During his association with Dorman, Long, he was responsible for its exceptional developments, especially since the last war.

Sir Ellis Hunter

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Gooch: The death has occurred of Mr. Arnold Joseph Gooch, a director of Parson Ltd., a subsidiary of G.K.N. Ltd. He was 54 and had been with the firm 40 years.

Mr. Gooch was well known in Midland iron and steel circles and led a varied social life, having been a member of the parochial council of Sutton Coldfield parish church, a member of Wylde Green Conservative Club, a former chairman of Wylde Green Conservative Tennis Club, and a committee member of the Institute of Sheet Metal Engineering.

MACHINE TOOL EXHIBITION

AN exhibition of British and Continental machine tools will be held by Rockwell Machine Tool Co. Ltd., at their showrooms at Welsh Harp, Edgware Road, London, N.W.2, from November 7-22 inclusive. The exhibition will be open from 10 a.m. to 5 p.m., Mondays to Fridays, and ample car parking space will be available.

Some 60 high production and toolroom machines of British and Continental manufacture will be displayed and demonstrated under power.

British machines will include Matrix thread grinders, worm grinders, jig borers, jig grinders and Matrix Thompson surface grinders, all of which are manufactured by Coventry Gauge and Tool Co. Ltd.

Among the Continental machines will be, for the first time in this country and direct from the recent Brussels Exhibition, Fritz Werner multi-channel programme controlled and tape controlled milling machines.

Other exhibits will include the new British Clearing Torc-Pac O.B.I. presses, the latest Thiel toolroom machines, Giddings and Lewis-Fraser "Hybormill" horizontal boring, drilling and milling machine, Diskus segmental wheel surface grinders, Jung fully automatic internal grinders, British built "U.S." Multi-slide machines, Peltzer and Ehlers cold forming machines and the latest Schutte six spindle automatic and tool and cutter grinders.

APPOINTMENTS and STAFF CHANGES

Mr. Gerry Smart has been appointed the first Building Products Technical representative of **James Booth Aluminium Ltd.**, as part of the company's new technical advisory service to architects and builders, etc.

Mr. Smart will operate from the London office at 50, Brook Street, London, W.1 (MAY 4966).

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Dr. D. H. Sharp has been appointed director (Technical) of the **Federation of British Industries.**

He will take up the appointment on the retirement of the present technical director, Major-General A. J. H. Dove, who is leaving the Federation at his own request in order to devote more time to voluntary work.

At present Dr. Sharp is assistant to one of the managing directors of Fisons Ltd.

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Mr. Gerard Young, J.P., aged 51, who has been elected as 326th Master Cutler, is the first Roman Catholic to hold this post. Mr. Young is chairman of **Tempered Group Ltd.,** which consists of six subsidiary companies which between them employ some 1,300 people. He joined Tempered Spring Co., now one of the six subsidiaries, in 1930 as management trainee at a salary of £1 per week. He was made a director in 1936, managing director in 1942 and became chairman on the death of his father in 1961.

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Mr. R. B. W. Bolland, formerly general manager of Head Wrightson Stockton Ltd., has been appointed London manager of **Head Wrightson and Co. Ltd.**

Mr. J. D. Eccles has been appointed director and general manager of Head Wrightson Stockton Ltd., Mr. G. F. Taylor has been appointed general manager of Head Wrightson Steel Foundries Ltd., and Mr. A. J. Long has joined the Head Wrightson Export Co. as general manager.

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The Incandescent Group of companies has appointed Mr. W. S. Sinclair as manager of its Cardiff office. Mr. Sinclair, who has 12 years service with the company, is already well known in the South Wales area.

Mr. H. Kay, B.Sc., M.I.Mech.E. has been appointed assistant managing director of the Engineering Division of **Tube Investments Ltd.**

* * *

Mr. H. Smith, chairman and joint managing director of British Ropes Ltd., Doncaster, has joined the board of **The United Steel Companies Ltd.**

Mr. G. D. Saul has been appointed chief inspector of **The United Steel Companies' Steel Peech and Tozer** branch. He succeeds Mr. W. M. Gladwin, who has retired.

Samuel Fox and Co. Ltd., a subsidiary of The United Steel Companies Ltd., announce that as a result of the retirement of Mr. G. Thickett, the following staff appointments have been made:

Mr. E. Hampshire will succeed Mr. Thickett as works manager (heavy departments). Mr. P. Thompson becomes assistant works manager (heavy departments), and will also act as manager of the billet mill.

Mr. V. G. Tyas is appointed manager of the billet finishing department and Mr. T. A. Rogers, assistant manager, billet bank, and Mr. R. H. Barrott, assistant manager, east bank, will be responsible to him.

Mr. C. Gray becomes manager of the bar and rod mill. Mr. K. E. Faulkner, assistant manager (rolling), Mr. J. Spence, assistant manager (heat treatment and warehouse), and Mr. D. R. Stone, assistant manager (planning and supplies) will be responsible to Mr. Gray.

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Mr. Leonard H. Short, M.C. (director of Overseas Operations, the English Electric Co., Ltd.), has been elected chairman of the Export Panel of the **British Electrical and Allied Manufacturers' Association.** The panel, comprising leading specialists in the electrical industry on export matters, is the chief advisory body to the BEAMA Council on overseas trade.

Mr. Short has been vice-chairman of the Panel for the past two years and succeeds Mr. E. V. Small (Consultant to Associated Electrical Industries Export Ltd.). The new vice-chairman is Mr. Harold P. Martin (sales director of C. A. Parsons and Co. Ltd.).

Mr. C. E. G. Nye

The George Cohen 600 Group Ltd. announce the retirement of Mr. C. E. G. Nye, M.C., from the board of George Cohen Sons and Co. Ltd.

Mr. Nye, who has been with the company for 40 years, joined Cohen's in 1921, at a time when one of their major undertakings was the breaking down of thousands of chemical shells.

In 1923 he was transferred to George Cohen and Armstrong Disposal Corporation where he was responsible for disposing of the Government's surplus medical stocks. After a short period with T. C. Jones and Co. Ltd., Mr. Nye moved to Brussels in 1929 as Administrateur Delegue of George Cohen Sons and Co. (Continental) Ltd.

On returning to England in 1931, he became manager of the Group Publicity Department, in addition to his technical and scientific advisory duties. In 1946 Mr. Nye was appointed a special director of George Cohen's and ten years later, when the Holding Company was formed, was elected a full director of George Cohen Sons and Co. Ltd.

Mr. Nye has for many years been closely associated with the publication of "600 Magazine," and has done much to develop that distinctive character which makes it one of the most widely read house journals in British industry.

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Mr. D. Parry Davies has been appointed a director of **Mond Nickel (Retirement System) Trustees Ltd.** and is succeeded as comptroller of The International Nickel Co. (Mond) Ltd. and Henry Wiggin and Co. Ltd. by Mr. L. C. H. Voss.

Mr. C. W. R. Edwards has been appointed secretary of The International Nickel Co. (Mond) Ltd. and Henry Wiggin and Co. Ltd. in succession to Mr. E. Vaughan. Mr. Vaughan remains a director of both companies.

(*Continued in page* 843)

Appointments and Staff Changes

(*Continued from page 842*)

Associated Electrical Industries Ltd., announce the following engineering appointments in the Turbine-Generator Division.

Mr. J. S. Hall, B.Sc.Tech., A.M.I.Mech.E.: divisional assistant chief mechanical engineer (Turbines).

Mr. J. V. Bigg, M.A., A.M.I.Mech.E., A.M.I.Mar.E.: divisional assistant chief mechanical engineer, (Auxiliary Apparatus) and chief engineer, general engineering department.

Mr. D. M. Smith, F.R.S., M.I.Mech.E., F.R.Ae.S.: consulting mechanical engineer.

Mr. D. F. Shannon, Ph.D., M.I.Mech.E.: chief engineer, Mechanical Experimental Development and Gearing.

Mr. F. R. Harris, B.Sc. (Eng.), A.M.I.Mech.E.: chief engineer, Advance Turbine Development and chief engineer, Gas Turbine Engineering Department.

Mr. J. C. London, B.Sc., M.I.Mech.E., A.M.I.C.E.: chief engineer, Large Steam Turbines.

Mr. A. A. Garson, M.A. (Cantab.), A.M.I.Mech.E.: chief engineer, Medium Steam Turbines.

Forthcoming Events . . .

November 8

Institute of Sheet Metal Engineering (Midland Branch). "Industrial Applications of High-speed Photography" by J. Hadland, in the Byng Kenrick Suite, College of Technology, Gosta Green, Birmingham. 6.45 p.m.

November 9

East Midlands Metallurgical Society. "Electron Beam Welding," by M. Harper, at the Derby and District College of Art. 7.30 p.m.

Institute of Metals (Birmingham Local Section). "The Welding of Metals," by D. R. Thorneycroft, at the College of Advanced Technology, Gosta Green, Birmingham. 6.30 p.m.

November 21

Institute of Sheet Metal Engineering (Midland Branch—Coventry Section). "Dieing Presses and Tooling" by J. Galway, at the Wine Lodge, Coventry. 7.30 p.m.

November 22

Institute of Sheet Metal Engineering (North-West Branch). "Spark Erosion as an Aid to Press Tool Making" by P. J. C. Gough, at the Engineers' Club, 17, Albert Square, Manchester. 7.0 p.m.

November 23

Institute of Metals (Birmingham Local Section). "The Cold Extrusion of Steel" by R. W. A. Wright, at the College of Advanced Technology, Gosta Green, Birmingham. 6.30 p.m.

November 28

Institute of Sheet Metal Engineering (South-West Branch). "Safety Measures in Sheet Metal Working" by R. K. Mawson (H.M. Deputy Senior Engineering Inspector of Factories) in the Engineering Lecture Theatre, Bristol University. 7.0 p.m.

November 29

Institute of Sheet Metal Engineering (Midland Branch—Wolverhampton Section). "Flow Turning" by E. J. Bennett, in the Wolverhampton and Staffordshire College of Technology, Wulfruna Street, Wolverhampton. 6.45 p.m.

Books for Your Library

Alloy Steels. Published by Samuel Fox and Co. Ltd., Sheffield. Price 42s. net.

THIS book, which is newly issued by Samuel Fox and Co. Ltd., Sheffield, is not a catalogue of Fox products but a collection of technical data set out in a variety of ways so as to be of maximum use to metallurgists.

In addition to data showing the effects of alloy composition, of mass and of heat treatment on the mechanical properties of steel, it includes information on the newer concepts of hardenability, isothermal and continuous cooling transformation.

It is probably the most comprehensive collection of technical data ever published on British Standard alloy steels. The book is divided into five sections under the following headings: products and finishes; Fox range of steels; data sheets; standard specifications; and information tables.

The data sheets cover 21 steels in the EN series and for each alloy cover Jominy hardenability, mechanical properties, physical properties, isothermal tranformation diagrams and continuous cooling transformation diagrams. Colour is used in the printing of all the diagrams to make them easier to translate. This book is excellently produced and will constitute a valuable addition to the literature.

ALUMINIUM LTD. ACQUIRES FOUNDRY IN GERMANY

ALUMINIUM LTD. announce that the company's fully-owned subsidiary, Aluminiumwerke Nuernberg G.m.b.H. has taken over operation of the Uphusen Works which are equipped to produce aluminium sand castings, permanent mould castings and die castings.

The construction of the expanded sheet and strip-rolling facilities at Goettingen in West Germany is also proceeding on schedule. This plant, when completed next year, will treble the company's aluminium sheet rolling capacity in Germany to about 25,000 tons per annum thereby providing an additional outlet for Alcan primary metal from Canada.

NEW PLANT FOR MAGNESIUM WILL AID BRITAIN'S ECONOMY

THE Power-Gas Corporation Ltd. of Stockton-on-Tees, a member of the Davy-Ashmore Group, has been appointed main contractors by Magnesium Elektron Ltd. for the engineering of a new plant to produce 5,000 tons per annum of magnesium at Hopton, near Wirksworth, Derbyshire.

The plant will extract magnesium of 99 per cent purity from local dolomite by a reduction process which has not previously been operated on a commercial scale in this country. The total value of the completed plant to Magnesium Elektron is expected to be in the region of £2,000,000.

Amalgamation and Change of Name

GOLD AND CO., (BIRMINGHAM) LTD. and Wm. Wassall and Son Ltd. who have been closely related for many years are now amalgamating and will trade under the name of Gold and Wassall (Hinges) Ltd.

Their new number is Tamworth 3391/2.

TITANIUM FOR GALVANIZING CARRIERS

THE successful use of titanium for carriers in hot-dip galvanizing is already widely known. Tests have now been carried out by the Metals Division of Imperial Chemical Industries Ltd., to broaden operating know-how and the following is a summary of results:—

1. Carriers going into hydrochloric acid pickle, then into zinc ammonium chloride pre-flux and finally into molten zinc, have been put through some thousands of immersions on production plant and the complete absence of corrosion indicates a life expectation of many years. Care must, however, be taken with positioning and execution of welds. Category: excellent, recommended.

2. There are grounds for expecting the same behaviour from carriers going into sulphuric acid pickle and then into pre-flux and molten zinc. Confirmatory long-term production tests of this process are awaited. Category: probably excellent; tests to be undertaken.

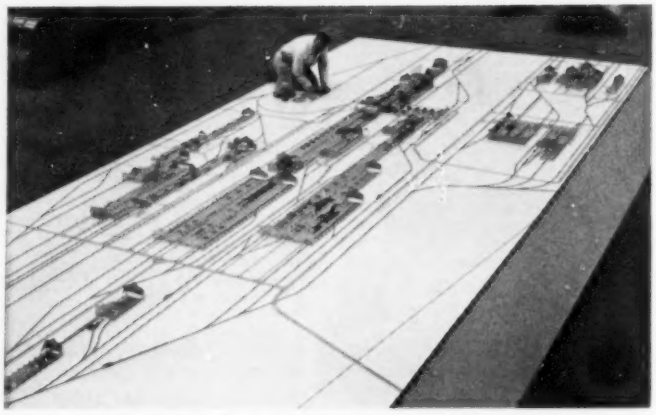
3. Titanium is entirely unsuitable for tanks and other parts *continuously* in contact with molten zinc. Gross corrosion takes place within a matter of days. Category: not recommended.

4. The behaviour of titanium immersed briefly but repeatedly in molten zinc, without intermediate pickling or pre-fluxing is under investigation and results will be available soon. In the meantime, the use of titanium is not recommended where it would be entering molten zinc repeatedly without intermediate pickling or pre-fluxing. Category: doubtful, under test.

THE SPRING MANUFACTURERS' RESEARCH ASSOCIATION

THE Coil Spring Federation Research Organization has now been admitted to full membership of the government's industrial research association scheme under the title of "The Spring Manufacturers' Research Association". This marks a big step forward in the growth and importance of this organization. Founded in 1945, it first received grant aid from the Department in 1947. Since then, under the Presidency of Mr. R. Salter Bache and the research direction of Mr. R. Haynes, it has grown in size and in industrial importance.

STEELWORKS MODEL FOR INDIAN INDUSTRIES FAIR



MADE to a scale of $\frac{1}{16}$ in. to a foot, this model shows the four main areas of the new Durgapur steelworks in West Bengal for which Davy and United Engineering Co. Ltd., (a member of the Davy-Ashmore Group) has been responsible as main contractors. The model was made in the model-making department at Stockton of The Power-Gas Corporation Ltd., another Davy-Ashmore subsidiary.

Davy-Ashmore are presenting this model to Hindustan Steel Ltd. for the latter company to display on their stand at the Indian Industries Fair in New Delhi. Hindustan Steel Ltd. is the company responsible for running the three new State steel plants in India on behalf of the Indian Government.

As members of ISCON, the British Consortium which is building the whole of the Durgapur steelworks, Davy and United are responsible for all the rolling mills, the wheel and axle plant, the central engineering maintenance department, the sleeper plant and the iron and steel foundry—in fact for more than one-quarter of the whole works. The total value of Davy-United's commitment for Durgapur totals some £29 million and involves over 70,000 tons of equipment.

DEVELOPMENTS FOR STANLEY WORKS

A NEW £250,000 development plan for their Sheffield factory has been announced by Stanley Works (G.B.) Ltd.

The major part of the plan is the erection of a modern 33,000 sq. ft. administration block on a site adjoining the factory. This will release valuable production space at present being occupied by offices in the factory buildings.

Announcing the plans the managing director, Mr. Owen Tannett, said that the developments were necessary to meet the increasing demand for tools in both the home and export markets and to facilitate the company's policy of expanding into new product fields.

He said that the factory's production of tools had risen by over 500 per cent since 1947 and the company was currently exporting 50 per cent of its production to 83 different countries.

The new buildings were designed by the company's architect Mr. Colin Hadfield of Sheffield.

PRODUCTION CONTROL AS A MEANS TO HIGHER PRODUCTIVITY

A CONFERENCE, organized by the Willesden and Hendon Productivity Association, will be held at the headquarters of the Federation of British Industries at 21 Tothill Street, Westminster, S.W.1, on November 22.

Chairman will be Mr. J. R. Wilkinson, director and general manager of Associated Electrical Industries (Manchester) Ltd., Switchgear Division, and speakers Mr. G. A. Hutcheson, managing director, National Union of Manufacturers Advisory Service, Mr. F. E. Pearce, director of sales, Personal Administration Ltd., Mr. G. Y. Elliott, senior consultant, Personnel Administration Ltd., and Mr. R. S. Geoghegan, director, E. G. Brisch and Partners. Further details from Mr. D. I. Duncan, A.E.I. Switchgear Division, 20 Neasden Lane, Willesden, N.W.10.

ELECTRONIC WEIGHER WILL SPEED PRODUCTION AT "MILL OF THE FUTURE"

THE first electronic weighing-in-motion system to be installed in a steel mill was recently shipped from the Yonkers, New York, plant of Fairbanks, Morse and Co. (largest industrial component of Fairbanks Whitney Corporation) to Great Lake Steel Corporation's mammoth new "Mill of the Future", now under construction at River Rouge, a suburb of Detroit.

The new high-speed weigher will help maintain the new mill's steel-making pace by accurately recording the weights of railroad cars as they arrive at the mill with raw materials, or leave with finished products—without interrupting production flow.

Weights of uncoupled cars are printed-out and fed into an adding machine as they move over a railroad track scale. The whole operation only takes about three seconds for each car, and rerouting delays frequently necessary for weighing in large plants in the past are entirely eliminated.

Heart of the new system is the Fairbanks Morse Model Q electronic high-speed weigher—a development which follows the company's weighing-in-motion systems.

Great Lakes Steel has so designed its new mill that all inbound and outbound traffic can be weighed. The system has therefore been designed for two-directional motion weighing, and is believed to be one of the first of its kind in the world.

The installation employs an 80 ft. mechanical-lever railway track scale linked to strain gauge load cells. A servo null-balancing system converts electric signals into printed weights. Loads of up to 330,000 lb. can be weighed on the Great Lakes' installation.

When the mill goes into operation later this year, it will produce steel coils up to 80 in. in width and weighing as much as 40 tons. The new rolling mill, part of the $300,000,000 expansion programme being completed in 1961 by National Steel Corporation, parent company of Great Lakes Steel, will be the first to have an electronic computer as an integral part.

JUNIOR INSTITUTION OF ENGINEERS AWARDS 1960-61

THE Council of the Junior Institution of Engineers has made the following Awards in respect of papers and lectures delivered during 1960-61.

The Institution Gold Medal: To R. F. W. Guard for his paper "Nuclear Fuels".

The Institution Silver Medal: To E. R. Brazier for his paper "Engineering in Chemical Works".

The Vickers Prize and Medal: To John Heywood for his paper "Radio Investigation of the Solar Atmosphere".

The Tookey Award: To Leonard Clegg for his paper "Boiler Management in Small Plants".

The Dunn Medal: To John M. Tebby for his lecturette "Formed Ends for Chemical Plant and the Like".

The Durham Bursary: To G. S. Taylor for his thesis, "A consideration of the Free-piston Gas-Generator Turbine as a Prime Mover for Automobiles".

London Structural Engineers Adopt Latest Shot-Blasting and Spray-Sealing Techniques

SANDERS AND FORSTER LTD. of Stratford, London, and Barking, Essex, (the structural engineering and standard steel building company of the Chamberlain Group of building construction, engineering and property companies), 3 Buckingham Palace Gardens, London, S.W.1, have now installed the latest equipment for automatically shot-blasting and spray sealing all fabricated steelwork produced at their recently enlarged works.

This service has been made possible by the greatly increased volume of work in the form of orthodox structural work and also in connexion with the S. and F. range of standard steel buildings both for the home and export market.

The company state that the installation of this equipment, which is considered to be the most up-to-date of its kind in the country, should increase the life of the final painted finish of the steelwork by about four times, and will greatly simplify corrosion problems relating to fabricated material exposed to sea water and humidity in transit by ship.

ALUMINIUM FOR NEW ZEALAND GRANDSTAND

ALUMINIUM was used extensively for the new 315-ft. long grandstand at the Auckland Racing Club's course at Ellerslie, New Zealand.

Noral "Industrial" profile stucco-embossed corrugated aluminium sheet, supplied by Alcan Industries Ltd., (formerly Northern Aluminium Co. Ltd), was used for the roof cladding. The sheets were fixed by studs fired into the purlins.

The back of the stand is clad with aluminium curtain walling with sprayed asbestos-cement infilling panels. The end walls are of stucco-embossed Noral "Snaprib" sheet, anodized gold.

Other applications utilizing aluminium include balustrades of Noral "Industrial" sheet backed with stucco-embossed sheet on the inside; capping and associated hardware; light fittings, door handles and restaurant appliances.

NEW ALUMINIUM PRODUCTS FOR BUILDING INDUSTRY

JAMES BOOTH ALUMINIUM LTD., one of the pioneers of the British aluminium industry, is to market for the first time, through its Building Products Division, a range of products designed for the building industry. It has also set up, under the direction of Mr. E. H. Laithwaite, B.Sc. Tech., the recently-appointed Building Products sales manager, a new technical advisory service to architects, builders, plumbers, etc., dealing with the application and installation of products made from aluminium and aluminium alloys.

A unique feature of the plan is a special building products warehouse at the Argyle Street Works, Birmingham, from which architectural extrusions, corrugated and troughed building sheets, flashing and roofing coil, and the associated fixing accessories, can be supplied immediately from stock instead of produced to order. Details of the initial range of James Booth building products are to be announced at the Building Exhibition in November.

New plant and equipment is being acquired, as part of the company's overall expansion programme, to enable an even wider range of these building products to be produced.

BUSINESS PROFESSOR FOR MANCHESTER UNIVERSITY

MANCHESTER UNIVERSITY has taken the lead in business education by appointing a visiting professor in industrial administration. Mr. Ronald Beresford Dew, M.A., LL.B., F.C.A., has been chosen for this post, the first of its kind in any British university. Professor Dew is assistant managing-director of Production-Engineering, Ltd. He was educated at Manchester and Cambridge Universities, and the Middle Temple, before serving in the Royal Navy throughout the war. He has recently been studying in U.S.A., leading American university business schools and American management consulting organizations.

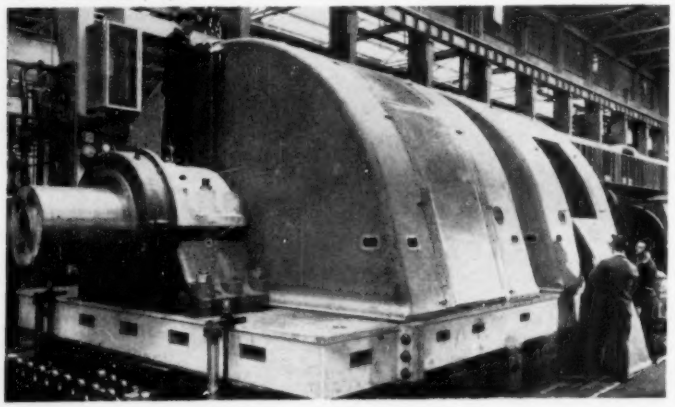
Expansion for Optoshield

OPTOSHIELD LTD., manufacturers of eye protection and other safety products, are transferring all their production and development departments to more spacious accommodation at Watford, to implement their extensive development programme.

The sales department and head office remain at 146 Clerkenwell Road, London, E.C.1, and orders should continue to be sent there.

Rolling-mill Drives

THE 6,000-h.p. motor illustrated is one of two manufactured by The English Electric Co. Ltd. for a twin drive in a steel rolling mill. It is fitted with reinforced plastic end shields which are lighter, and, because of better insulation properties, smaller and cheaper than conventional covers of steel or aluminium. These end shields, over 12 ft. dia., were made by the company's Reinforced Plastics Division at Freckleton, Lancs., using "Fibreglass" FGE 2,000 chopped strand mat and polyester resin.



Hydrostatic Extrusion Developed At NEL

New Method Gives Improved Qualities at Lower Pressures

A NEW method of extrusion developed by the DSIR's National Engineering Laboratory gives products with more uniform mechanical properties and requires much lower pressures than the conventional process. Extrusion pressure is applied hydrostatically without any direct contact between ram and billet. Tests of the process have so far been restricted to pure aluminium and an aluminium alloy, but the laboratory is taking the work a stage further by investigating the cold extrusion of other metals, especially steels.

In the new process a cone is machined at one end of the billet so that it fits closely into a die with a conical entry. The die forms the exit from a cylindrical high-pressure chamber containing a liquid, such as glycerine, castor oil, or a dispersion of molybdenum disulphide in oil. The other end of the chamber is closed by the ram of a hydraulic press. As the ram moves into the chamber, pressure builds up in the liquid, which transmits the extrusion pressure to the billet. The material is extruded through the die without any direct contact between ram and billet. The fluid acts as an efficient lubricant and makes it possible to use conical-entry dies with very small die angles.

In addition the nosing of the billet reduces the amount of work expended in deforming the metal and hence the maximum extrusion pressure required. Reductions in extrusion pressure of 30 to 40 per cent have been obtained in the laboratory tests. With pure aluminium, the maximum extrusion pressure for the production of rod at an extrusion ratio of 7, through a conical-entry die with a 20 deg. included angle, was 17 tons per sq. in. compared with a pressure of 32 tons per sq. in. for a conventional extrusion through a square-entry die. With the alloy (0.7 per cent magnesium, 1 per cent silicon and 0.7 per cent manganese), the pressure was 29 tons per sq. in. compared with 43 tons per sq. in. by conventional methods. All these figures are for extrusion from an unheated billet. The distribution of hardness over the cross-section of the extruded rod was much more uniform than usual, and this will often be an important advantage. These results suggest that cold extrusion of high strength materials will be possible.

Electrical Equipment For Mill Modernization

ELECTRICAL equipment valued at £45,000 has been ordered from the Motor and Control Gear Division of Associated Electrical Industries Ltd. by Stewarts and Lloyds Ltd. of Corby. The equipment is required for the modernization of a continuous weld mill to increase output of 1½ in. steel tubing to 750 ft. per min. or 4 in. tubing to 320 ft. per min.

The work will involve the replacement of the present mill saw with a special American type of flying saw which calls for more powerful electrical equipment having wide and easily controlled variation, together with an electronic device for matching saw performance with that of a selected mill stand.

The flying saw will be driven by a 25-h.p. a.c. mains powered motor but to facilitate overall operational speed control of the mill, and achieve greater accuracy of pipe length cuttings, direct current will be used to power all seven of the actual d.c. mill motors and the d.c. saw crank motor. This direct current will be provided by an AEI type Ward-Leonard motor-generator set comprising a 400-h.p. mains powered a.c. synchronous motor driving a 220-kW. d.c. generator with a 40-kW. constant voltage exciter, and a small 10-kW. "booster" generator. Six of the eight 40-h.p., d.c. motors will drive mill stands, one the saw crank, and one the back-end roll when this is in use in conjunction with the pre-heating of strip. Speed matching of saw performance and a selected mill stand will be by means of a magnestat, or magnetic amplifier, fed by the output of two tachometer generators; differences of output will be automatically adjusted by the 10-kW. booster generator.

CHANGE OF ADDRESS

THE Newcastle-upon-Tyne area sales office of Alcan Industries Ltd., (formerly Northern Aluminium Co. Ltd.), has moved to new premises at Newgate House, Newgate Street, Newcastle-upon-Tyne. This office, under the management of Mr. N. P. Campbell, will continue to serve County Durham, Cumberland, Northumberland, Westmorland and Scotland for all forms of Noral aluminium and aluminium alloy materials. The telephone number is Newcastle-upon-Tyne 22107 but the Telex number, 21917, remains unchanged.

FIRST NICKEL FROM INCO'S NEW MINE

By sea from Hudson Bay

SHIPPED at the Hudson Bay port of Churchill, at the beginning of the very brief open season, the first consignment of nickel from Thompson, Manitoba, arrived at Swansea recently en route for the Clydach works of The International Nickel Co. (Mond) Ltd.

Inco's 185 million dollar Thompson project is expected to increase the world's annual nickel supply by some 37,500 tons, half of which is destined for consumption on this side of the Atlantic, to meet the steadily increasing demand.

Formally opened as recently as the end of March, the new plant is expected to provide Europe with 6,000 tons before ice closes the direct shipping route from Churchill this year.

Power for Industry-- Man Into Space

THE impact of Space Research on engineering development as well as the association of modern trends in fuel utilization and power generation with man's ultimate conquest of outer space, have prompted Provincial Exhibitions Ltd. to offer a section of Olympia's Grand Hall to the British Interplanetary Society to mount and sponsor Britain's first International Exhibition of Space Research and Technology as an integral part of the new Power Generation and Clean Air Equipment Exhibition, to be held in London from May 2-11, 1962.

The two-way theme of the exhibition will be the relationship between industrial power on earth and the exploration of Space. A series of lectures will be given under the auspices of the Institute of Fuel, while the British Interplanetary Society will hold a 2-day symposium on "Auxiliary Power Generation for Space Vehicles" and "Materials in Space Technology". There will also be discussions on the impact of Space Technology on new branches of the aviation, electronics and engineering industries and new careers open to young men as a result of current advances.

Further information may be obtained from Provincial Exhibition Ltd., City Hall, Deansgate, Manchester 3. Telephone: Deansgate 6393, or British Interplanetary Society, 12 Bessborough Gardens, London, S.W.1. Telephone: TATe Gallery 9371.

£500,000 EXPORT ORDERS FOR STEEL, PEECH and TOZER

THE United Steel Companies' Steel, Peech and Tozer branch have recently secured export orders to a total value of £500,000. They were gained in the face of fierce competition, particularly from Continental steelmakers.

Largest individual order came from behind the Iron Curtain. Centrozap, the central buying agency for iron and steel in Poland, has called for 4,300 tons of steel bars and further small tonnages of hot-rolled trip.

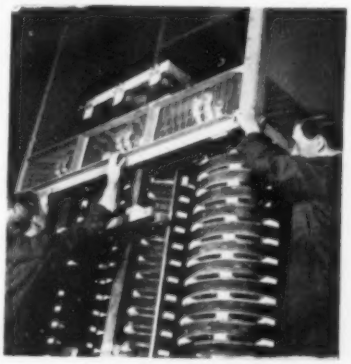
Other orders for railway wheels, tyres and axles have been received from Mexico, Finland, India and Cuba. These orders have been obtained in addition to the normal business with regular export sources and from British Railways and other carriage and wagon builders in this country. Deliveries will begin immediately and will extend over the next few months.

CHANGE OF ADDRESS

THE address of the Manchester office and warehouse of Norton Grinding Wheel Co. Ltd. is now Wharf Road, Sale, Cheshire. Telephone: Sale 8285/7, Telex 66116.

TRANSFORMERS FOR NEW MOTOR-CAR FACTORY

AT the Wimbledon factory of Foster Transformers (a subsidiary of Metal Industries Ltd.) a ventilated sheet-steel case is lowered on to the core and coils of a 1,500-kVA air-cooled transformer, one of a number being manufactured for the Ford Motor Company's new factory at Halewood in Lancashire.



Publications for Industry

A recent issue of "Sif-Tips" contains many informative articles well illustrated with pictures and diagrams.

One feature is a technical article on the manufacture of refrigerators, with special reference to the major part that welding has to play in fabricating the body-work of refrigerators. This article is a comprehensive summary of the techniques involved in the welding processes, and it demonstrates the advantages of Sifbronze welding.

Other interesting features are an argument for and against preheating in welding operations. There is also an article about the manufacture of petrol and diesel fuel pumps. In the construction of these pumps a number of welded and brazed joints are required and they are chiefly pipe and flange joints on such diverse metals as copper, steel, bronze and cast iron.

"Sif-Tips" is produced and published by Suffolk Iron Foundry (1920) Ltd., of Stowmarket, Suffolk.

* * *

Rocol Laboratories have recently made a thorough examination of the requirements of varnishes for production of resin-bonded molybdenum disulphide lubricating films on metals and other surfaces. As a result Rocol Ltd. is continuing to market Rocol Molytox Plus as a general-purpose varnish, especially when ease of application is a factor to be considered, but is now also listing Rocol Molydite Plus, based on a thermo-setting resin as bonding agent.

The new grade, Molydite Plus, gives a tougher bonding but requires more care in application and baking at a comparatively high temperature (200° C. = 392° F.).

The two varnishes are described in Leaflet I.F.S.111 available from Rocol Ltd., Rocol House, Swillington, Leeds, Yorks.

* * *

A new monthly periodical covering the whole field of phosphating materials, phosphating equipment and applications of phosphate coatings has been published by Translation and Technical Information Services, 32, Manaton Road, London, S.E.15.

Many large industries now use phosphate coatings to provide a base for the paint subsequently applied to motor cars, domestic appliances and metal goods of all kinds, for lubrication during the cold forming of metals and for electrical insulating purposes, particularly with sheet steel. Hitherto there has been no periodical to cover the trade news, literature and patents appearing about this field.

"Phosphating News" is an attempt to fill this gap with a small monthly review of phosphating information collected from all over the world and is directed at both the user of phosphating processes and the suppliers of methods, chemicals and equipment. It will be issued in duplicated form during the second week of every month and is supplied on subscription at a cost of £2 a year or £2 15s. airmail (U.S.A. and Canada $6 a year or $9 airmail).

* * *

The latest series of data sheets issued by Johnson, Matthey and Co., Ltd. covers their range of high purity metals. In recent years, the rapid advance of technical developments in many fields has brought about a demand for a wider variety of high purity metals and a greater diversity of physical forms. Johnson Matthey have investigated and perfected techniques for producing an extensive range of high purity metals and for fabricating many of them into rod, sheet and other forms.

In the data sheets, information is given on 38 metals including noble, rare earth and certain base and rarer metals. The general properties of each element are tabulated and details are given of the forms of current production. In most cases the metals are available in more than one grade, the metallic impurity contents being expressed in parts per million.

Johnson Matthey have also issued a new data sheet describing their cobalt-platinum permanent magnet alloy Platinax II.

This material is the latest development in magnetic alloys of the cobalt-platinum system, and with a $BH_{(max)}$ of 9.2×10^6 gauss-oersteds is one of the most powerful permanent magnet materials known. Before its final heat treatment it can be rolled, drawn, or machined without difficulty.

As well as general data previously included, the new publication gives information on the heat treatment process, on reversible permeability, and on behaviour at elevated temperatures.

Copies of the data sheets and full particulars are available from the company, at 73-83, Hatton Garden, London, E.C.1.

* * *

On the recommendation of the Export Publicity Council the Board of Trade Journal has published a survey on marketing and publicity in East Africa. Aimed particularly at exporters new to the area the survey gives topographical, economic and political information about Kenya, Uganda and Tanganyika. It tells how to tackle the market, advises on local advertising methods, and on choosing an agent. It shows the distribution of local purchasing power, gives information about inland freight services and charges, and sums up the market for both consumer and capital goods. There is information about trading conditions in the area and statistics showing local imports and exports. Future development and the present location of industry are also featured. There are maps and tables of interest to exporters and the survey is illustrated with photographs which portray something of the challenge of the market. A reprint of the survey is available on request, free of charge, from the Export Publicity and Fairs Branch, Board of Trade, Horse Guards Avenue, London, S.W.1.

* * *

The 1962 edition of the I.W.S. Supervisor's Handbook and Diary has been published by the Industrial Welfare Society and promises to be even more successful than its two predecessors. The new handbook appears in a smart maroon cover of Dutch balacuir with gold lettering.

As in previous years this material was chosen for its high resistance to grease and oil smears—and it is washable, too.

Once again this five-shilling pocket encyclopaedia is packed full of facts, figures and information of real practical value to supervisors in all industries.

There is a seven-days-to-a-page diary section and gold blocking of company names can be arranged at small extra cost.

* * *

The Export Council for Europe's third Report on trading opportunities for British firms describes market opportunities in Belgium and Luxembourg, Finland, Greece, Ireland, the Netherlands and Turkey. The Council's first report, issued in May, entitled "Trading Opportunities in Europe" (Part One), covered Austria, Denmark, France, Italy, Norway, Portugal, Spain, Sweden and Switzerland. The second, "Trading Opportunities in West Germany," was published in June.

In carrying out this survey 27 members of the Council travelled 25,000 miles, visiting countries with a total population of 280 millions—100 millions more than are contained in the United States.

The Report is available from The Export Council for Europe, 21, Tothill Street, London, S.W.1. Price 5s.

NEW PLANT and EQUIPMENT

A monthly review of new machines, equipment, processes, etc., of interest to the producer and user of sheet metal

Double-crank Power Press

IN metal drawing and stamping operations to produce shells of greater depth than diameter, the metal must be worked with the minimum of molecular fatigue. The impact velocity of the ram must therefore be kept low enough to prevent (1) tearing of the blank and (2) excessive wear on tools and dies.

However, with single-crank presses, the speed of the ram is maximum at the point of impact and diminishes increasingly until the end of the stroke. To keep within permissible limits, it is therefore necessary to decrease the revolutions of the press correspondingly which decreases (1) the efficiency of the press and (2) the output of the press by reason of the increased number of strokes, each of which requires annealing, trimming and scaling.

Ideal operating conditions require (1) the lowest possible velocity of the ram at the point of impact and (2) constant speed of the ram during the working stroke. Some of the screw and hydraulic presses fill these requirements but their operating speed (and productivity) is low.

Etablissements Hubert-Juy-Legros of Paris have patented a device which is an efficient practical application of the two ideal principles but retains the rapid operation of the standard press with the following characteristics: impact velocity of ram 18 m. (59.055 ft.) per min.; operating speed of press 90 strokes per min.; nearly constant speed of ram during working stroke; acceleration of ram speed during approach and return stroke.

On a standard machine and at the same press speed and length of stroke, the impact velocity of the ram would be 60 m. (196.850 ft.) per min. Fig. 1 illustrates the difference in the performance curves of the HJL double-crank press and a standard type of press.

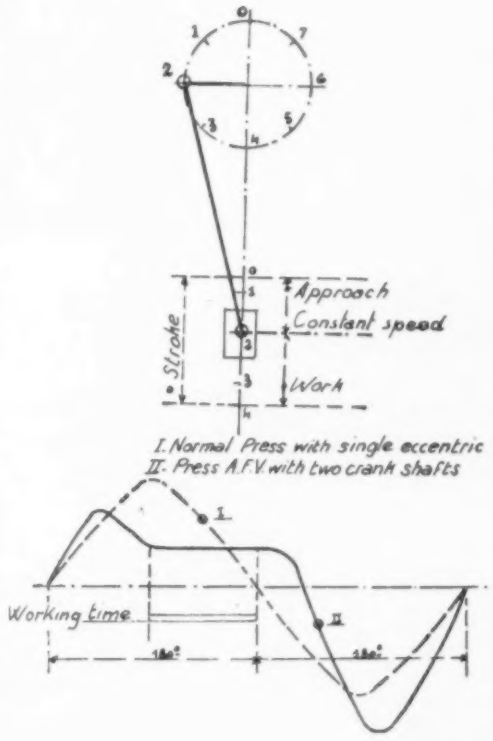
The double-crank construction of the HJL press makes it possible to exert the maximum effort of the ram at the point of impact on the work whereas the contrary is true of the single-crank press. The improved performance and increased productivity of the HJL presses is based on the very simple principle of two cranks revolving at the same speed and acting on the ram by a system of push rods and ball and socket joints.

All types of automatic work feeds can be mounted on these presses. Hubert-Juy-Legros manufactures revolving bolster plates operated by a Geneva movement. The presses can also be equipped with the patented HJL pneumatic blank-holder. This accessory can be easily moved out of the way and its advantages are well known.

These improved accessories and the advantages of the new double-crank system make the HJL presses the ideal machines for all stamping and embossing operations. They are claimed to be the perfect solution to the problem of obtaining deep or delicate (aluminium or aluminium alloy) shells and make it possible to find substitutes for nearly all the metals now required for these operations.

Agents in the U.K. are The Press and Shear Machinery Co. Ltd., Acton, London, W.3.

Fig. 1.—Performance curves of double-crank and standard presses



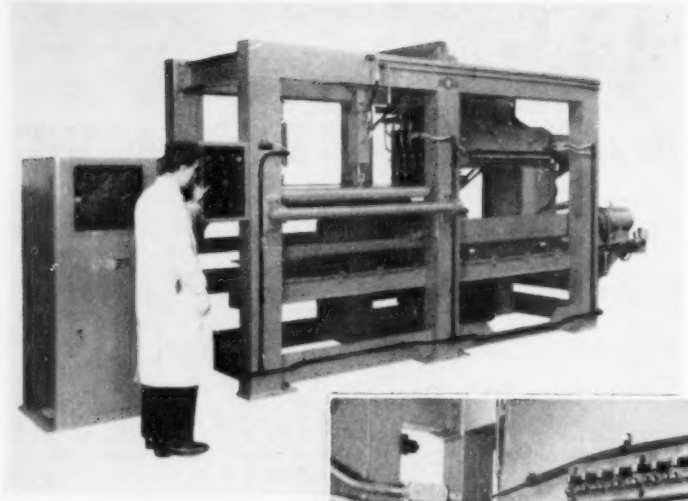
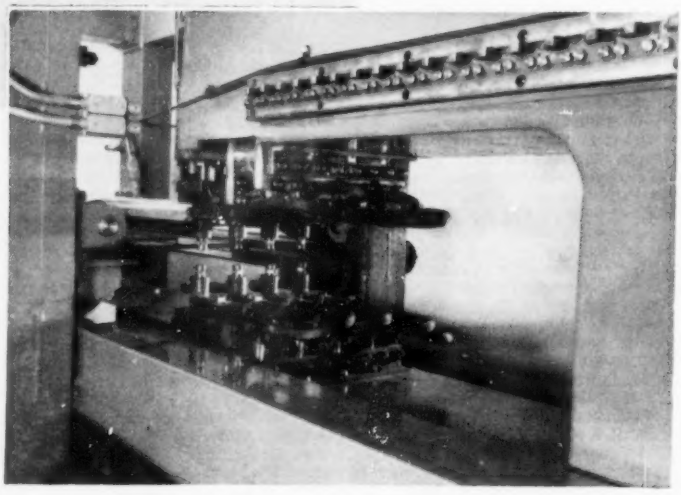


Fig. 2 (left).—Multi-spot welder

Fig. 3 (below).—Leading edge being fed into position



Fully Automatic Traversing Multi-spot Welder

THE Sciaky SOM 200 fully-automatic traversing multi-spot welder (Fig. 2) is extensively used in continuous process strip mills. Its function is to make a lap joint by high-speed multi-spot welding between the trailing edge of one coil in process to the leading edge of the following coil to form a continuous strip for passing through the processing equipment.

The general construction of the machine lends itself to the strip line application insomuch that the six-poster main frame allows free movement of the strip and carries the pass and side rollers, also the hydraulically operated strip clamps. The traversing "C" frame which also carries the eight welding heads is housed on a roller track inside the six-poster making the whole unit compact and robust.

The "C" frame is traversed by means of a lead screw driven by a 3-h.p. electric motor and the drive is interrupted by using a pneumatically operated clutch.

Rated at 200 kVA. nominal, two heavy-duty 100-kVA. transformers are used. The secondaries are arranged in "push pull", this arrangement does not suffer the inherent losses experienced with conventional spot welder secondary loops.

Electronic control is effected by a Sciaky thyratron timer, phase-shift heat control, and ignitron contactors housed in a separate cubicle which enables it to be sited away from the machine. The operator's push-button controls are in a convenient position giving fully automatic or manual selection. The machine is capable of handling strip up to 42 in. wide and welds thicknesses of 0.100 in. + 0.100 in. silicon steel strip. The surface condition is as received from the hot-strip mill or cold-reduction mill.

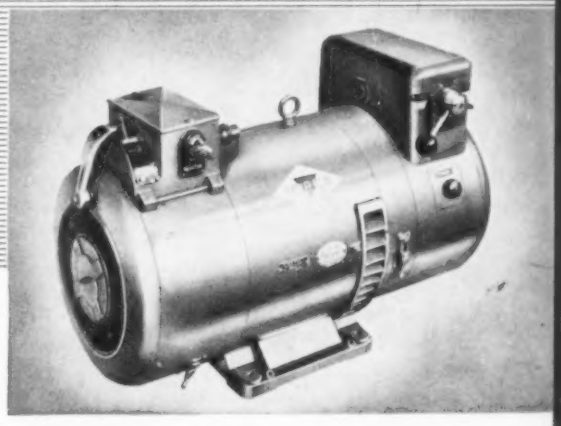
The weld cylinders are hydraulically operated and capable of exerting pressures up to 5,000 lb. Both top and bottom electrode assemblies retract giving an unrestricted flow to the strip and allowing the "C" frame to return to the start position after completing a weld sequence.

The quality of the welding produced on these machines withstands passing through oil-fired, or electric roller-hearth annealing furnaces at 913° C., flash pickle tanks, scrubbing and pickling units, side trimming units, wheelabrating plant and other strip handling equipment where strip tensions up to 1,000 lb. per sq. in. are experienced.

The complete sequence of operations takes approximately four minutes or under, depending on the width of the strip. The trailing edge is cropped and inched into position, the leading edge is cropped and fed into position as Fig. 3. The operator clamps the strip for welding, this initiates the fully automatic welding cycle and four welds are made in line simultaneously; this is repeated across the width of the strip. The pitch of the welds can be varied by means of adjustable cams. Having completed the sequence across the strip the heads retract and the "C" frame starts to return to the neutral

(*Continued in page* 852)

The Murex "REVEX" Motor Generator



A new compact high quality 300/400 amp welding set–

The Murex " Revex " generator is a compact, light weight, high quality d.c. welding equipment suitable for a wide range of applications. It operates on a unique brush shift principle and gives stepless current adjustment over a range of 50 to 300 amp. for continuous hand welding at 30 volts and up to 400 amp. for intermittent welding. The equipment has a high open arc voltage which assists the welder in striking an arc even under the most difficult circumstances. The equipment is specially designed to operate at a speed of 3,000 r.p.m. and it is built to give the maximum service with the minimum of maintenance. It complies with BS 638 : 1954 and can be supplied with a number of optional extras including a trolley for ease of handling and a portable regulator by means of which the voltage can be varied infinitely and independently of the current adjustment. Please write for full details.

MUREX

GD 844

MUREX WELDING PROCESSES LTD., WALTHAM CROSS, HERTS.

position, simultaneously the clamps release the strip which then progresses unimpeded.

This operation must be carried out with the minimum of delay, as when the strip is clamped the reservoir loop is being used to continue the process. Halting the process must be avoided as material remaining too long in the furnace becomes scrap.

This plant is also supplied using Sciaky patented 3-phase balanced load which operates at a power factor of not less than 0.85. The greatly reduced power demand and tailor-made secondary wave form produces a weld which is claimed to be superior to that of single-phase machines.

Magnetic Sheet Floater

RAPID MAGNETIC LTD., Lombard Street, Birmingham, 12, are manufacturing a sheet floater (Fig. 4) designed specially to assist punch press operators finding difficulty in separating thin, oily steel sheets when feeding to presses. Burred edges on previously stamped sections further aggravate the problem. The Rapid unit also saves operator's time and removes the risk of damaging dies by feeding double sheets.

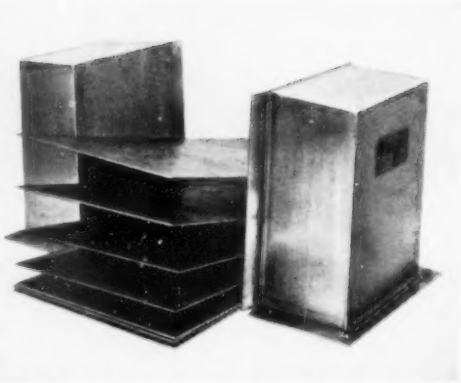
The powerful Alcomax magnets incorporated in this device create repelling magnetic fields in each sheet so that they are separated widely enough for the top sheet to be removed easily by hand.

A wide variety of sheet sizes and shapes can be handled effectively up to a thickness of about 12 gauge. With large rectangular sheets floater units are concentrated at one corner.

Shearing Machine

AS a development of their "Series 25" precision guillotines Rushworth and Co. (Sowerby Bridge) Ltd. have introduced two new ranges of shearing machines (Fig. 5) having larger capacities. These are "Series 38" and "Series 50" the first of which has a mild steel capacity ranging from 6 ft. × $\frac{3}{8}$ in. to 12 ft. × $\frac{3}{8}$ in. and the second from 6 ft. × $\frac{1}{2}$ in. to 8 ft. × $\frac{1}{2}$ in.

These machines are of all-steel frame construction and are designed to give a very clean sheared edge by the provision of forward sloping slideways and a low rake angle of the top blade beam. The blades have four cutting edges and are adjustable over their full length.



The drive is by worm and wheel with wormshaft, the electric motor and flywheel being mounted co-axially. Transmission is by a multi-jaw dog-type clutch which is solenoid-operated and controlled by either a foot switch or a pendant. The hold-down is effected by individual hydraulic plungers operated from a master unit.

The standard fittings include two table brackets for the front and two side guides for the top of the table. Lighting is provided on the cutting area and a waste chute to push cut off blanks away from the machine is fitted. A number of optional extras can be supplied such as two 4-ft. long table brackets with floor supports, squaring arms from 4 to 10 ft. in length, a shadow cutting line indicator and a dial-reading precision back gauge in lieu of the ungraduated standard gauge. Special-quality blades are available for use with stainless steel.

The "Series 38" range has a speed operation of 50 strokes per min. in the smaller capacity machines and 37 strokes per min. in the larger capacity units while the "Series 50" models operate at 33 strokes per min. The depth of gap in all cases is 9 in.

Further details may be obtained from the manufacturers at Sowerby Bridge, Yorkshire.

(*Continued in page* 854)

Fig. 4 (above).—Magnetic sheet floater

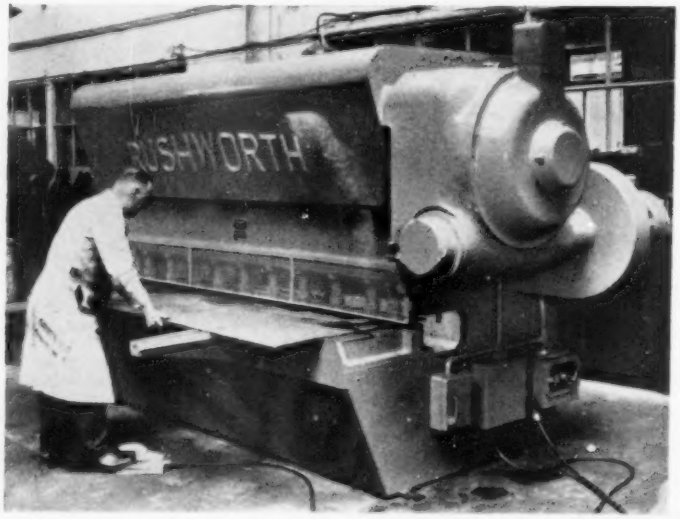
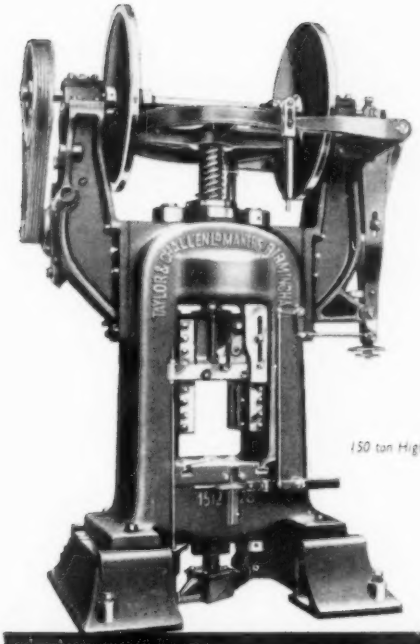
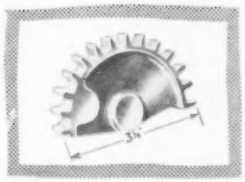
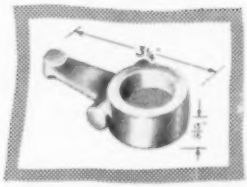


Fig. 5 (right).—Shearing machine



150 ton High Speed Screw Press

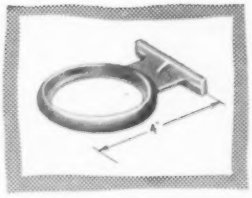


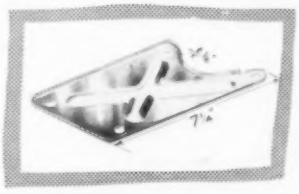


SCREW PRESSES

WE ALSO MAKE

Double Action type Drawing Presses
Open-fronted Presses
Double sided Presses
Single and Double Crank Presses
All types of Automatic Feed Presses
Minting machinery
Cartridge machinery





TAYLOR & CHALLEN LTD *BIRMINGHAM 19*

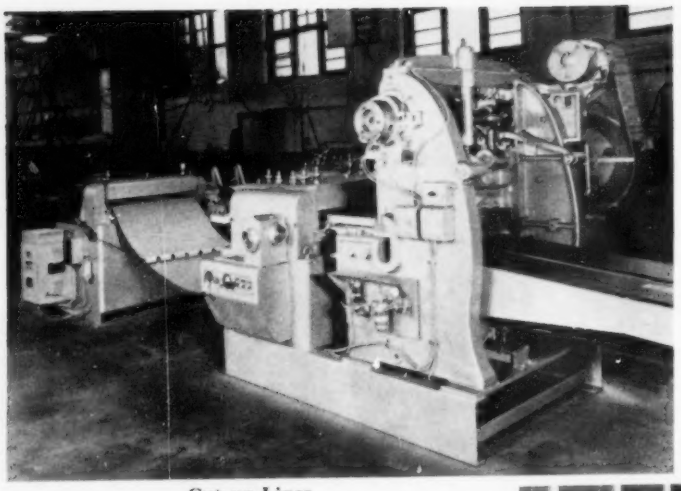


Fig. 6 (left).—Coil cut-up line

Fig. 7 (below).—Strip thickness measuring device

Cut-up Lines

COIL cut-up lines made by Press Equipment Ltd., Hunters Vale, Birmingham 19, are now available with a new electro-mechanical metering and measuring device, which supersedes the conventional end stop and retracting run-out track. End stop systems have limitations where it is required to cut long lengths, and particularly where there is a wide range in width of strip. Furthermore the space occupied by the track and mechanism at the rear of the shear unit is often detrimental.

The metering and measuring device operates in conjunction with the straightening unit of the line, detects the amount of material passing through the outgoing pinch rolls, and automatically stops the straightener and operates the shear when it has metered off the required length. It incorporates automatic re-set to provide instantaneous re-start of the straightener and measure as the shear blades open.

Setting of length required is by two dials, one for feet and the other for inches, the former requiring only a coarse setting. Accuracy on lengths up to 12 in. is in the order of ±0.015 in., and, unlike end stop arrangements, does not deteriorate on longer lengths.

The output side of the shear unit is left completely clear for a conveyor, or any take-off or stacking arrangements that the user may require. Fig. 6 shows this device fitted to a 36 in. wide × 0.048 in. coil cut-up line with decoiling unit incorporating power driven pinch rolls to draw the material off a mandrel mounted between roller bearings, the speed of the pinch rolls being automatically governed by a Heenatron variable speed drive controlled from a catenary detector between the decoiler and straightener. This drive operates through a magnetic transducer, a.c./d.c. electronic excitation unit, tachometer generator, and d.c. geared motor, and provides a constant amount of material in the loop irrespective of varing consumption by straightener and shear. The line is capable of handling aluminium strip down to 0.007 in. thick for which purpose the decoiler and straightener pinch rolls are backed up, and a bridle is provided at the input side of the straightener.

Strip Thickness Measurement

THE "Microcorder" is a device for measuring the thickness of metal strip, manufactured by the Micrometrical Mfg. Co., Michigan, U.S.A.

The new equipment consists of three essential units: (1) an amplimeter, (2) a recorder, and (3) a pilotor. Working together they provide a quick, accurate means of measuring and recording variations in thickness of metal strip.

The amplimeter amplifies electronic signals from the tracer as it is piloted along the strip stock under its own power. A selection dial on the front panel of the amplimeter makes possible a choice of five different vertical magnifications; (1) 5μ in. per division—50,000X; (2) 25μ in. per division—10,000X; (3) 100μ in. per division—2,500X; (4) 250μ in. per division—1,000X; (5) 1000μ in. per division—250X.

The recorder provides a permanent chart record of the thickness variations and makes possible a choice of three different horizontal magnifications: (1) 0.002 in. per division—250X; (2) 0.004 in. per division—125X; (3) 0.010 in. per division—50X.

The 4-in. wide strip chart is easy to read and reproducible by conventional means. The self-propelled pilotor contains the tracer mechanism and will traverse an 8 in. strip in approximately 90 seconds. Frequent measurements on sample strip have resulted in savings in both time and money by pointing to strip stock that is non-standard. Mill rejects have been reduced 60 to 70 per cent by one prominent steel company.

(Continued in page 856)

Factory Heating—2

It is impossible in this Data Sheet to describe in detail every type of electric heater on the market, but a representative selection is dealt with below. Each type of building presents its own problem, and the best plan is to seek advice from your Electricity Board, who will be pleased to help.

'OFF PEAK' ELECTRIC HEATING

Because the 'off peak' load makes use of generating and distributing equipment when it would otherwise be idle or underloaded, the Electricity Boards offer cheap 'off peak' tariffs. Three types of 'off peak' heating systems are available, namely:

(a) Hot water storage heating: This consists of a conventional hot water radiator or panel heating system through which hot water from a large storage vessel is circulated. The water in the storage vessel is heated electrically during the 'off peak', low tariff hours and is circulated when required through the radiators or panels.

(b) Block storage heaters: These heaters consist essentially of a number of firebrick blocks which are heated up during the 'off peak' hours by means of suitable electric heating elements. The storage heaters are clad with a layer of suitable heat-insulating material and are housed in a sheet metal casing, the design being such that the stored heat is gradually dissipated throughout the day by means of radiation and convection. These heaters can easily be installed in existing buildings.

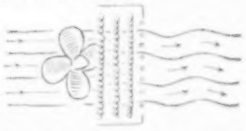
(c) Floor warming: In an 'off peak' floor warming installation, electric heating

Plan view of room *Isometric view of heating cable*

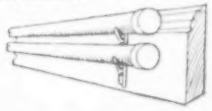
cables or ducts housing withdrawable cables are embedded in the concrete floor of the building. The cables are switched on and the floor is heated up during the 'off peak' hours, and the mass of concrete and screed of the finished floor has sufficient thermal storage capacity to heat the building during the period when current is not available. This method is only applicable to new buildings.

DIRECT ELECTRIC HEATING

(a) Unit heaters: These consist of a bank of electric heating elements fixed in a casing on which is mounted a fan which draws or blows air over the heating elements and discharges it in the required direction. Such units are mounted on the walls or stanchions or hung from the roof members in appropriate positions throughout the works.



(b) Infra-red heaters: These consist of heating elements usually of the sheathed metal or silica tube type mounted in a polished reflector. They operate at temperatures from 700° to 900°C, and give off the greater part of their heat output by radiation. They are mounted overhead and are particularly useful for providing local areas of comfort in spaces not otherwise heated.



(c) Tubular heaters: These take the form of tubes approximately 2" in diameter containing an electric heating element and are available in lengths from 2 to 17 feet. The normal loading is 60 watts per foot run and the surface temperature is from 180° to 200°F. They are usually placed round the walls at skirting level, but also can be used at high level in order to prevent downdraughts.

For further information get in touch with your Electricity Board or write direct to the Electrical Development Association, 2 Savoy Hill, London, W.C.2. Telephone: TEMple Bar 9434.

Excellent reference books on the industrial and commercial uses of electricity and reprints of articles and papers are available.

E.D.A. have available on free loan in the U.K. a series of films on the industrial uses of electricity. Film and Book catalogues and Publications List sent on request.

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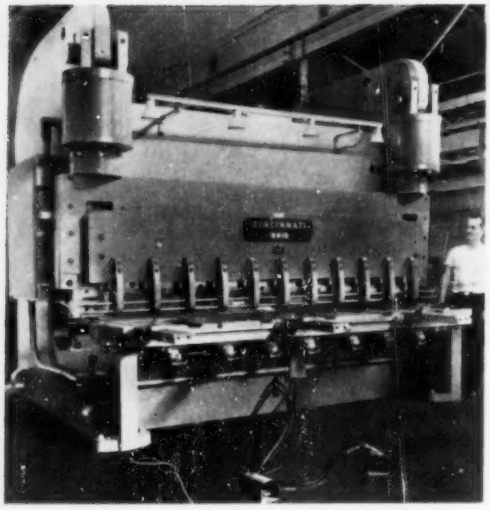


Hydraulic Shear

THE new series 8N10 Cincinnati hydraulic shear (Fig. 8), equipped with the standard Cincinnati "adjustable rake" feature, has a nominal capacity of 1 in. × 10 ft. mild-steel plate, and is made by The Cincinnati Shaper Co., P.O. Box 111, Cincinnati 11, Ohio, U.S.A.

The rake of the upper knife is adjustable from 0 in. to ¾ in. per ft. This feature permits the shearing of materials that exceed the nominal capacity of the machine by adjusting the rake upward (maximum mild-steel plate shearing capacity of the 8N10 is 1¼ in.). When shearing materials lighter than the nominal machine capacity, rake can be adjusted downward to a very low angle to minimize distortion in the back piece.

Centralized controls for the adjustment of rake, stroke, power back gauge and start-stop control are convenient to the operator and simple to operate. Ball transfers in the table facilitate materials handling and provide for greater efficiency. The gap frame permits the cutting of plates longer than the nominal machine length, and electric foot pedals provide remote control operation of the shear.

The hydraulic drive of the shear is powered by a 40 h.p. motor. The drive unit incorporates a manifold block which brings the valves together in one compact assembly. High pressure joints are reduced to a minimum. The exclusive Cincinnati clevis-mounted operating cylinders are self-aligning; automatic horizontal movement of these units throughout the full rake adjustment insures greater life of piston and cylinder packings.

Other features include hydraulic holddowns, light beam shearing gauge, front gauges and support arms, work chute at rear of machine, inclined ram, interlocked construction, automatic pressure lubrication, exclusive Cincinnati swivel end-guide bearing (ensures ram alignment endwise), four edge knives, and jack lugs for quick, easy installation.

Wide Face Wheel Head

A NEW wide-face wheel head (Fig. 9), specially designed for continuous buffing of aluminium, brass, or steel coil stock, has recently been added to Murray-Way's line of specialized polishing and buffing machinery and complete automatic production lines.

These new heads may be placed in tandem and angularly positioned for cross-cutting action. The complete head oscillates, allowing more uniform buffing, and a special jog automatic wheel positioner is provided to compensate for buffing wheel wear.

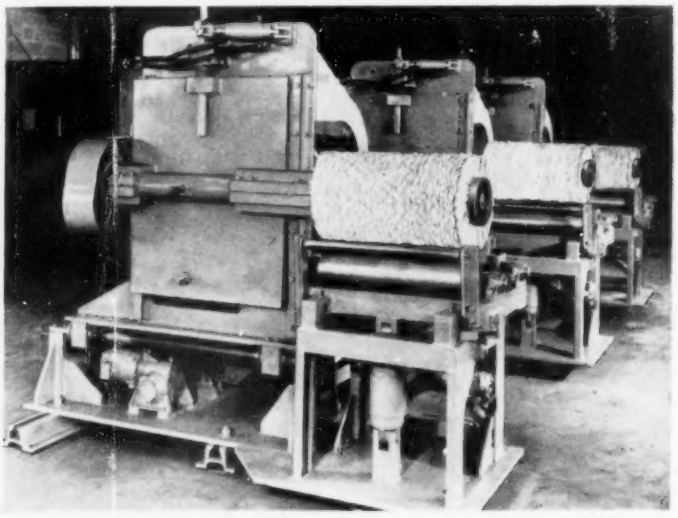
A billy roll supports the strip at the buffing point. When stitched or welded coil ends pass under the buffing head, the billy roll automatically "drops out", allowing the strip to run free.

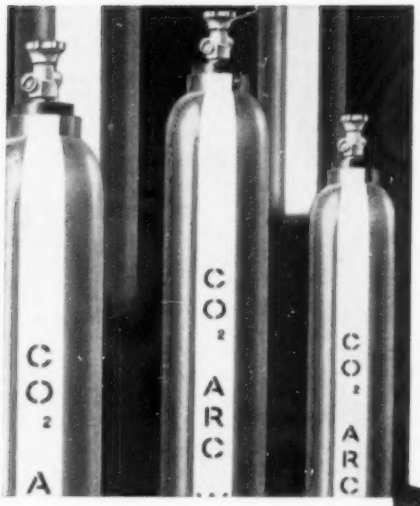
Buff sections are mounted on a separate, balanced, bearing-supported sleeve. The buffing heads shown are 24 in. wide, but provisions may be made for use of larger or smaller widths. The address of the Murray-Way Corporation is P.O. Box 180, Birmingham, Michigan, U.S.A.

(*Continued in page* 858)

Fig. 8 (above).—Hydraulic shear

Fig. 9 (right).—Wide face wheel head





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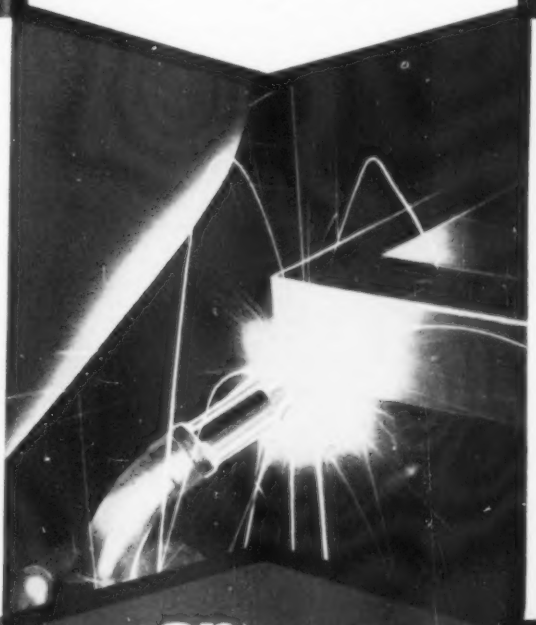
One of the new range of Lincoln CO_2 Welding Units using economical low-pressure carbon dioxide shielding, is the new SPRITE CO_2 Welding Unit, which, with the Lincoln FW1 Lightweight Hand Welding Gun, will continuously weld in all positions down to 20 g. sheet, even where poor fit-up is experienced, with minimum distortion.
For quality welds to Lloyds Standard the manufacturers, Lincoln Electric Company Limited of Welwyn Garden City, Herts, recommend DCL's constant composition CO_2 in the newly designed syphon cylinder for all their equipment, both semi and fully automatic.



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Servo-driven Multipress

THE Denison Servo-driven Multipress "600" is a high-speed, hydraulic press designed specifically for stamping operations. Capable of delivering over 600 ram strokes per min., this press is a 4-column, platen type with a vertical frame. Bed area between columns is 20 in. × 20 in. Maximum daylight is 15 in. Daylight is adjustable by means of a simple screw-thread from the maximum to a minimum of 12 in.

The press employs a close-circuit servo-type hydraulic system. Harmonic cams provide work strokes of $\frac{1}{4}$ in., $\frac{1}{2}$ in., $\frac{3}{4}$ in., 1 in., $1\frac{1}{2}$ in., 2 in. and 3 in. Punch break-through is adjustable in increments of 0.001 in. and controlled without the use of positive stops for quieter operation. Maximum break-through adjustment is $\frac{1}{2}$ in. Hydraulic power for the press is furnished by a floor-mounted pump unit. Both press and pump rest on vibration-absorbing mounts. To facilitate tooling set-up and change-over, all four sides of the press frame are open below the bed. A drive shaft projects from both upper right and upper left sides of press, providing a convenient power take-off for feed etc.

Electric controls, including speed control, inching, cycle and emergency stop, are panel-mounted on a separate console which may be remotely positioned. The console is equipped with a counter which permits automatic control of the press for a predetermined production run. The press stops when the predetermined number of cycles has been attained. Continuous automatic cycling is also standard.

Control of ram pressure is readily accomplished by a simple adjustment on the pump unit. Both frequency of ram strokes and pressure may be changed while the press is operating. A servo-loop hydraulic system automatically adjusts the speed of the feed drive shaft for perfect sequencing with ram action.

A number of accessories are available for use with this press, including feed mechanisms, variable-speed straighteners, and bolster plates. Sole agents in Great Britain are Gaston E. Marbaix Ltd., Devonshire House, Vicarage Crescent, S.W.11.

Ultra-rapid Cutting Machine

ANDERSTON CLYDE ENGINEERS LTD., Irk Vale Works, Chadderton, Manchester, announce an entirely new product, the Neva-Scimitar ultra-rapid cutting machine (Fig. 10). Claimed by the manufacturers to be suitable for every kind of workshop, this machine handles round or square bars, tubes, channels, and sheet metal.

The Neva-Scimitar cuts very rapidly, light and heavy gauge bar, strip, tube, and sheet: in steel, plastics and non-ferrous metals. For example, 2 in. × 2 in. × $\frac{5}{16}$ in. angle-iron can be cut in less than two seconds to maintain a rate of 1,500 cuts per hour; $1\frac{5}{16}$ in. dia. tube can be cut at the rate of 2,000 cuts per hour. The cutter is a safe, well-designed, robustly built machine powered by an 8-h.p. electric motor, specially designed for high-speed running. The special 21-in. dia. alloy cutting blade is fixed directly on the motor shaft and is easily removable for re-sharpening. A re-sharpening service is available at normal cost. Capacities are: Rod or bar up to 4 in. in dia., tube up to 4 in., heavy sections up to 6 in. × 4 in., strip up to 20 in. × $\frac{3}{8}$ in., and sheet-metal up to $\frac{3}{16}$ in. thick by any size.

The machine permits equally high speed mitre cutting, shortening, groove cutting, notch cutting, and profile cutting of angles in sheet metal.

It is claimed that the machine causes no distortion and cutting surfaces are barely warm. Cuts are smooth, clean, and burr-free.

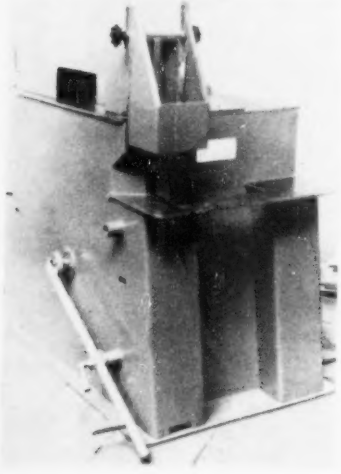

Fig. 10 (left).—Ultra-rapid cutting machine

Eye Magnet Probe with Magnifier

OF compact design and stainless-steel construction, the latest item of First Aid equipment, the eye magnet probe with magnifier, is being marketed exclusively by General Trade Equipment Ltd., 82-90, Seymour Place, London, W.1, and consists of a magnifying glass which adjusts along the length of a fluted barrel. At either end of the barrel are two caps, one containing a powerful magnet, the other a looped piece of catgut. As shown in Fig. 11, metal splinters, etc., can easily be removed from the eye by the magnet, the magnifying glass being focused on the actual object in the eye.

Similarly the catgut end can be used for removing foreign matter of non-metal content.

Fig. 11 (right).—Eye magnet probe

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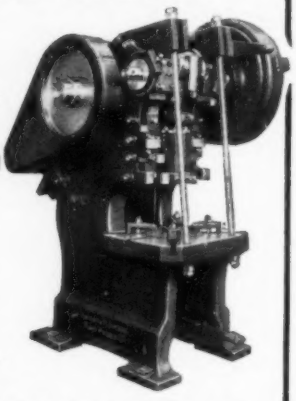

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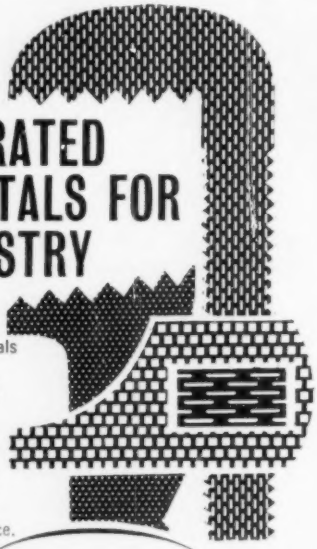

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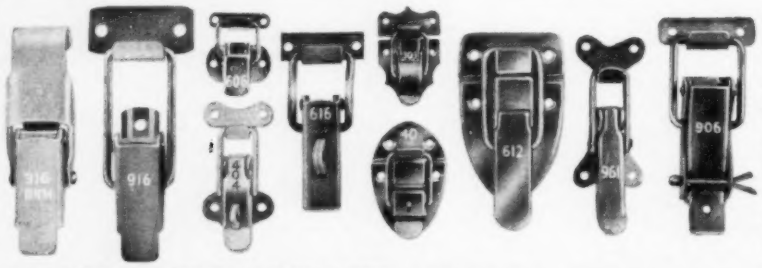

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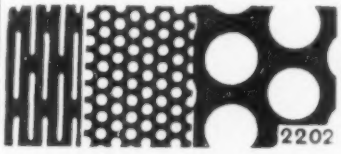

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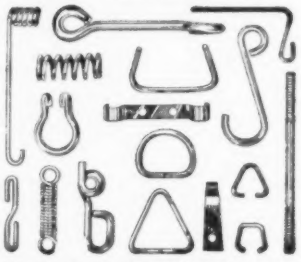

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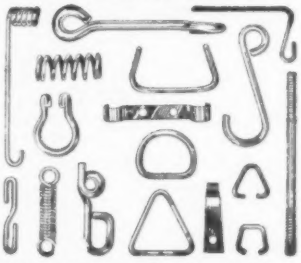

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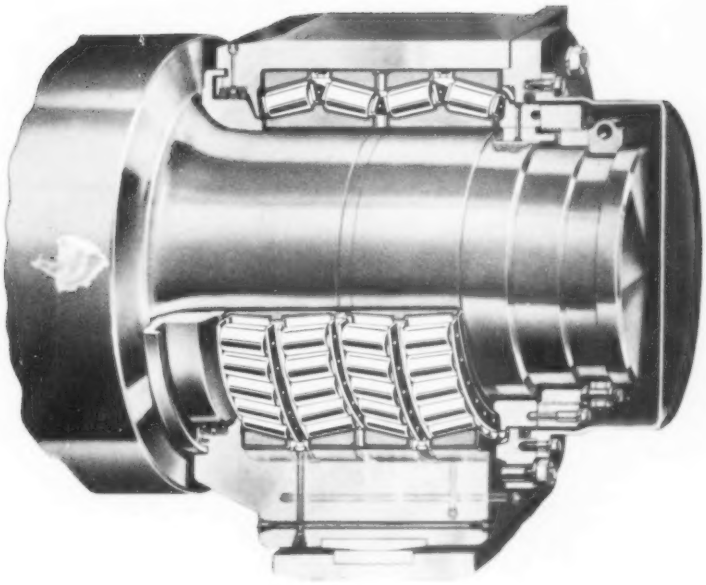

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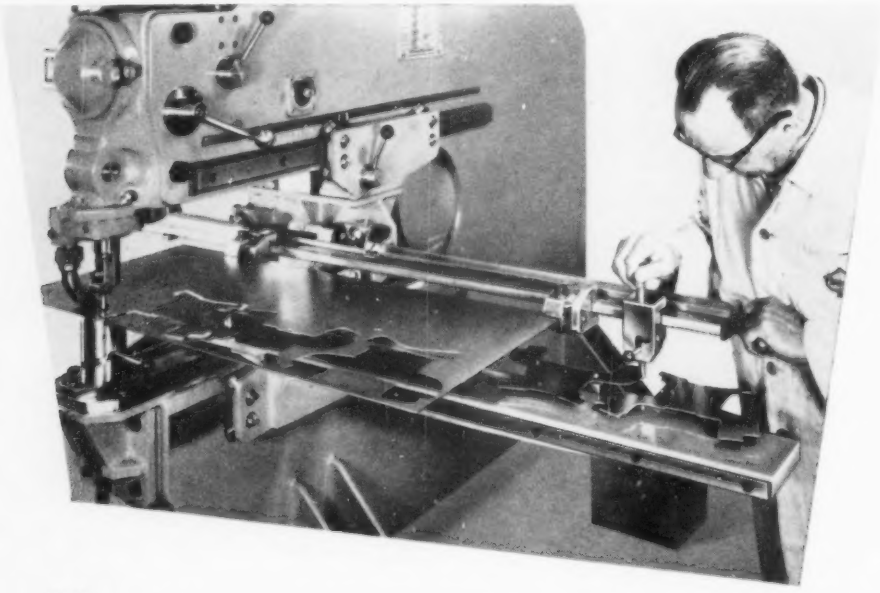

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